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BOTANICAL GAZETTE

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CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY. LIV.

NEW OR PECULIAR NORTH AMERICAN HYPHOMYCETES. III.

ROLAND THAXTER.

(WITH PLATES IV AND V)

DURING a brief visit to Jamaica in the winter of 1890-91, the writer obtained, among numerous other interesting coprophilous forms, two peculiar genera of hyphomycetous fungi, both of which have been kept constantly in cultivation ever since. Although both these types are conspicuous, and appear to be widely distributed, no reference to either of them has been found in the literature, and it is assumed that they have been thus far overlooked.

The most striking and peculiar of these genera, to which I have given the name *Heterocephalum*, has the appearance of a very large Aspergillus, of a delicate orange-yellow color, from the head of which project numerous radiating spines or bristles, visible to the naked eye, the whole (*fig. 1*) recalling the conditions seen in Actiniceps. This resemblance is further strengthened from the fact that the spiniferous head is borne on a stalk which appears to be composed of numerous slender ascending hyphae, and at first sight one might be inclined to place the plant among the Hyalostilbeae. An examination of the early development of this fructification, however, makes it evident that it belongs to a quite different type, which appears to be, in some respects, unique among the Hyphomycetes.

The vegetative portion of the fungus consists of a copious

mycelium of rather slender septate hyphae from which the fertile hypha usually arises as a lateral branch of relatively large diameter, which becomes abruptly differentiated. As this fertile hypha commences to rise above the substratum, a number of vegetative hyphae, or branches from them, grow toward it; and, as it elongates, apply themselves closely to its surface, growing upward as it develops and more or less completely corticating it, except in the region of its free extremity. When the fertile hypha has attained its full height the free tip, ceasing to elongate, becomes abruptly swollen, forming a head much as in Aspergillus (*fig. 2*), the whole surface of which soon becomes papillate with young sporiferous branches (*fig. 3*). The corticating hyphae meanwhile, being enabled to overtake the head, apply themselves closely to its surface and begin to push between the young sporiferous branches, by which they are soon more or less completely concealed. At the same time, also, they begin to branch more or less copiously, and the extremities of these branches, growing outward with the sporophores, extend rapidly beyond them (*fig. 8*), and eventually form the radiating septate bristles above referred to. Their development, however, is not confined to mere elongation; since, just below two or sometimes three of the lowest septa, they give rise to whorls of lateral branches, which, growing tangentially, by branching and intertwining eventually form an envelope like basket-work that incloses the sporogenous branches completely, and through which the bristle-like hyphae appear to project. The sporogenous hyphae in the meantime branch successively in an irregularly umbellate fashion, the branchlets becoming more numerous as the process is repeated. The basal cells and those of the main branches become greatly enlarged, closely compacted, and more or less adherent, so that they are with difficulty crushed apart; while the ultimate branchlets of the third or fourth order bear an irregular umbel of sporiferous branchlets, from the tips of which the minute oval spores are successively abjointed (*figs. 4–7*).

The head, which strongly suggests the pseudoperithecium, if it may so be termed, of the more highly differentiated species of

Gymnoascus, is thus a remarkable combination of two elements of independent origin. The conspicuous portion, which forms the main bulk of the head, consists of sterile elements derived from sterile hyphae in the mycelium, whose development runs parallel to that of the fertile hypha and whose function is evidently connected with spore dispersion. At maturity the bristles and other sterile elements of the head become echinulate through a more or less copious deposit (of calcic oxalate?) and adhere very readily to any object which touches them; while at the same time the whole head separates at a touch from its attachment to the stalk, carrying with it the mass of spores which, though not involved in mucus, are nevertheless adherent in a more or less compact mass. The successively abjointed spores do not appear to remain united in chains, though two or three may often be seen thus adherent, and, judging from the dense contents of the compacted and firmly adherent sporogenous branches, it seems not improbable that they may continue to be abjointed even after the head has become separated from the stalk which bears it.

The spores germinate readily, and the fungus fruits abundantly on nutrient agar of various kinds, the fructifications being usually more or less gregarious, often so much so that adjacent heads adhere to one another over a considerable area and may be lifted in a continuous mat.

Although this fungus has been under cultivation for twelve years on various substrata, and under varied conditions, no ascigerous fructification has as yet made its appearance. That it belongs among the Plectascineae nevertheless, and that an ascigerous condition of this nature will eventually be found, can hardly be doubted. The same fungus has been received from another source within the past year, having fruited spontaneously in transit, on some goat's dung, in a vial hermetically sealed with wax, which was sent to my assistant, Mr. A. F. Blakeslee, from the Philippine Islands. It may thus be assumed that the plant has a wide distribution in the tropics from its independent occurrence in antipodal regions.

The second form, which I have called *Cephaliophora*, made its

appearance on a bit of mongoose dung picked up in a ravine near Kingston. It forms at first a cottony mycelium composed of septate branching hyphae of very rapid growth, which soon collapse more or less completely, sending up at intervals short branchlets which become sporophores, and under a hand lens appear to rise directly from the substratum. These sporophores consist of short, broadly clavate branches, the distal portion swollen with variable abruptness, and from the surface of the more or less distinctly differentiated head thus formed the spores arise directly as in Oedocephalum. The spores, which are fawn colored to pale chocolate-brown in the mass, are quite unlike those of other genera of this type in being multiseptate, thick-walled, and subcylindrical. The septa are transverse and commonly three in number, but vary from two to rarely as many as six. The basal cell is never functional and always colorless, and others of the cells, especially the terminal ones, are often empty at maturity, the contents becoming concentrated in the remaining segments. The mature spores have very thick walls and are able to retain their vitality air-dry for more than a year, germinating readily in water, or on nutrients, in the ordinary fashion.

Like the first type described above, this fungus has been in constant cultivation for twelve years in my laboratory without showing any signs of the production of an ascigerous condition. The same species has been obtained and cultivated, for periods ranging from two to six years, from Liberia, Africa, from Java, and from China, under conditions which leave no doubt of its origin from these localities, so that it may be assumed to be a common form of wide distribution throughout the tropics.

A second and closely allied species of the same genus was also obtained on material sent from Porto Rico, and although it was at first believed to be a mere variety of the first, its differences, after five years of cultivation, still remain so constant that its separation seems warranted. Its spores are differently shaped, and normally once, less often twice, septate, the terminal cell being relatively large and usually the only functional segment. Its habit of growth in tubes is also less luxuriant, the sporiferous hyphae forming a stringy coating on the agar, usually more or

less characteristic, while the color of the spore mass is distinctly more rufous.

HETEROCEPHALUM, nov. gen.—Vegetative mycelium consisting of fine, septate, branching, colorless hyphae growing on and in the substratum. Fertile hyphae abruptly differentiated, erect, stout, swelling distally to form a well-distinguished terminal head, the whole surface of which gives rise to sporophores several times subumbellately branched, the ultimate branchlets abjointing successively continuous hyaline spores. The fertile hypha corticated by sterile hyphae which grow upward with it, eventually forming a special envelope about the sporiferous portion of the head.

Heterocephalum aurantiacum, nov. sp.—Color pale clear orange-yellow, sometimes almost salmon colored. Sporogenous hyphae four to five times successively subumbellately branched, the irregularly bottle-shaped sporophores borne in terminal groups of about six or eight from branchlets of the third or fourth order. Spores minute, oval to oblong, somewhat irregular in size and outline. Corticating hyphae about six to ten in number, giving rise to numerous (about twenty-five to fifty, more or less) straight, rigid, bristle-like, tapering, septate branches radiating in all directions from the head, often terminating in a slight, rather abrupt, enlargement, and producing, in whorls just above their two lower septa, several lateral branchlets growing tangentially, branching and intertwining to form a spherical envelope, like basket-work, about the fertile head and coherent spore mass within; the radiating setae and their branches becoming more or less prominently echinulate at maturity. Spores about $3.5 \times 3\mu$. Fertile hyphae 1.5–3^{mm} high by 8–14μ in diameter. Radiating setae about 600–1500μ in length. Diameter of head, including spore mass, 300–375μ; including envelope, 500–750μ.

On dung of toad, Kingston, Jamaica (1890–91); on goat dung, Philippine Islands.

CEPHALIOPHORA, nov. gen.—Vegetative hyphae copious, branching, septate, colorless. Sporophores arising as short branches from the hyphae, which become more or less abruptly enlarged distally to form a variably differentiated head, from the

surface of which the spores are produced. Spores once to several times transversely septate, becoming brownish, the sterile basal segment narrowed to form a more or less distinct pedicellate attachment.

Cephaliophora tropica, nov. sp.—Sporophores very variable, the heads nearly spherical or more or less elongated, short-stalked or almost sessile. Spores hyaline, becoming fawn- to pale chocolate-brown in the mass, translucent, darker at the septa, two- to five-septate (normally three-septate), subcylindrical; the sterile basal cell tapering to a well-marked pedicellate attachment. Spores, average about $35\times16\mu$, maximum about 50×19–20μ. Diameter of head, average about 28–35μ. Average length of fertile branch, including head, 60–75μ.

On mongoose dung, Kingston, Jamaica; on ass dung, Liberia; on rat dung, Java; on mouse dung, China.

Cephaliophora irregularis, nov. sp.—Similar to the last; the spores in the mass more reddish-brown, the habit of growth somewhat different. Spores very variable in form and size, normally once, sometimes twice, septate; the terminal cell only (as a rule) fertile, usually broadly rounded, often broadened, and not infrequently bilobed. Average spore measurements 25–$30\times18\mu$, maximum about $36\times30\mu$.

On mouse dung, Porto Rico.

HARVARD UNIVERSITY.

EXPLANATION OF PLATES IV AND V.

The figures were drawn with camera lucida and reduced in reproduction. The approximate magnifications are as follows: *fig. 1* × 60; *figs. 2–3, 11–15, 17–19* × 390; *figs. 4–7, 10, 16* × 860; *figs. 8–9* × 100.

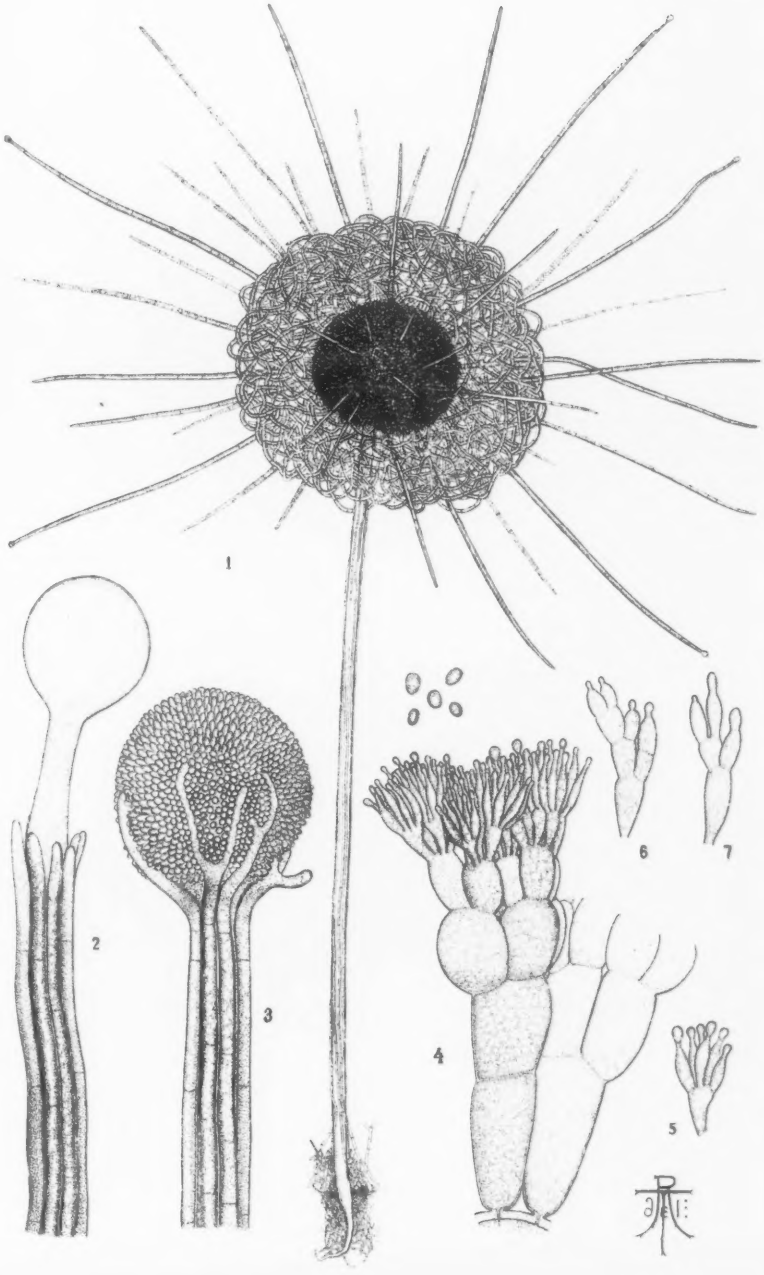
FIGS. 1–10. *Heterocephalum aurantiacum.*

FIG. 1. General habit; the dark central portion of the head represents the spore mass surrounding the sporophores.

FIG. 2. Terminal portion of a fertile hypha, its tip enlarged to form the fertile head, which has not yet been overtaken by the corticating hyphae.

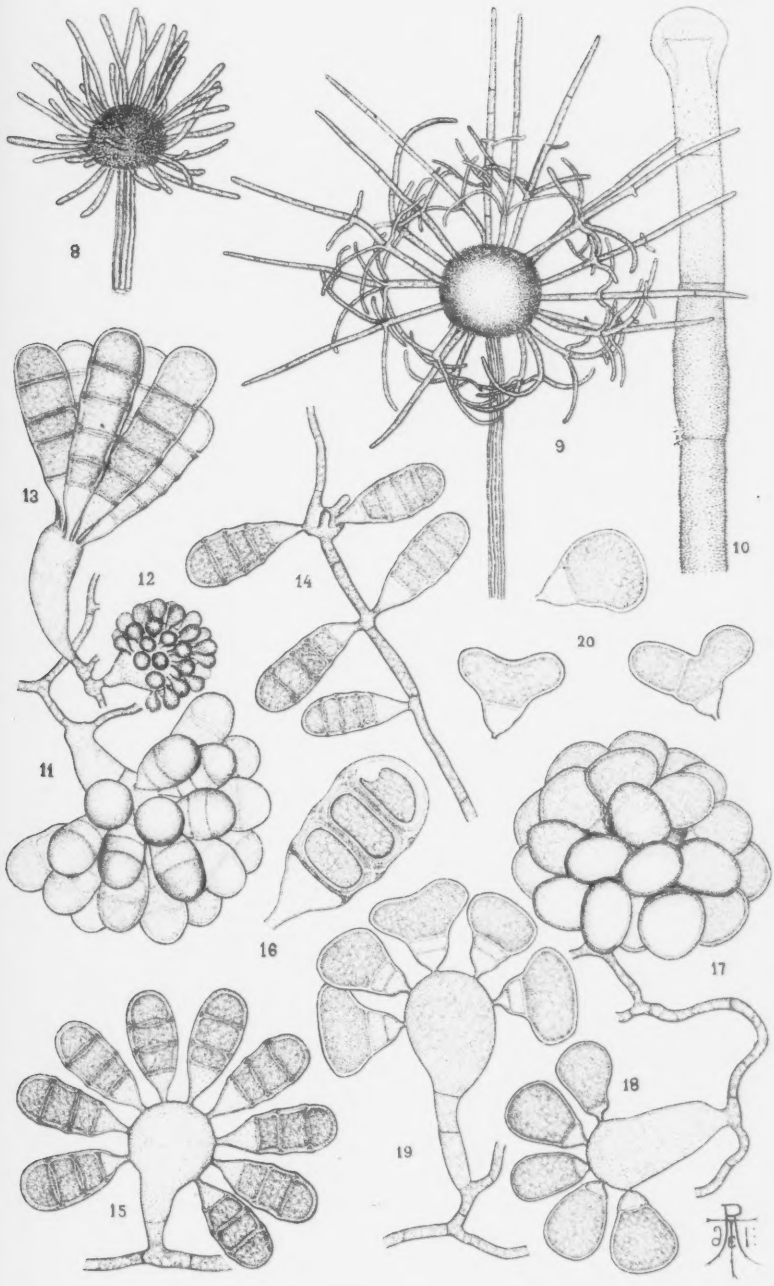
FIG. 3. Fertile head covered with young sporogenous branches, among which the branching tips of the corticating hyphae are beginning to push.

FIG. 4. Small portion of fertile head showing sporogenous branches and their origin; above, four spores.



THAXTER on HYPHOMYCETES.

HELIOTYPE CO., BOSTON.



THAXTER on HYPHOMYCETES.

HELIOTYPE CO., BOSTON.

FIG. 5. Branch of the fourth order bearing tuft of sporiferous branchlets.

FIGS. 6–7. Young sporogenous branches from which branchlets of the third and fourth order are budding.

FIG. 8. Young fertile head, the subclavate branches of the corticating hyphae projecting from among the young sporogenous branches.

FIG. 9. A more mature condition, in which these branches are becoming bristle-like and are giving rise to the whorls of lateral branchlets which form the sterile envelope shown in *fig. 1*.

FIG. 10. Tip of one of the mature setae, showing echinulation.

FIGS. 11–16. *Cephaliophora tropica.*

FIG. 11. Normal sporiferous head with spores *in situ*.

FIG. 12. Young head with spores just developing.

FIG. 13. Abnormally elongate head with unusually long 4–5-septate spores.

FIG. 14. Abnormal development of spores directly from the hyphae.

Fig. 15. Normal head seen in optical section.

FIG. 16. Normal fully mature spore.

FIGS. 17–20. *Cephaliophora irregularis.*

FIG. 17. Head with rather broad spores.

FIG. 18. Head in optical section showing normal spores.

FIG. 19. Head in optical section with broad biseptate spores.

FIG. 20. Three spores.

CHEMICAL STIMULATION AND THE EVOLUTION OF CARBON DIOXID.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XLIV.

EDWIN BINGHAM COPELAND.

[*Concluded from p. 98.*]

As HAS already been noted, the interpretation of my results with metallic poisons is uncertain. When the most of the experiments were performed it was without a suspicion that the CO_2 evolved from the plants could be anything but an immediate product of respiration. The results were presented in that light to the Botanists of the Central States at their meeting of December 1901. Since that time I have shown, and will present the evidence in the following tables, that these metallic salts can drive CO_2 from solutions of such salts as are in the cell sap. In any experiment, then, it may come directly from the proteid or from the sap, and it probably comes from both.

Before the experiment began each subject of experiment was left over night in its bottle, with a current of CO_2-free air passing through it *as rapidly as during the experiment.* The CO_2 evolved is expressed in cubic centimeters of normal acid for each hour. The data of the first experiment, except the temperature, are copied in full from my notebook, to illustrate the nature of the record. The poison was applied by opening the bottle and dropping in with a pipette enough of a concentrated solution to give the desired strength. The bottle is open very few seconds. I have satisfied myself repeatedly, by putting in water in the same way, that this introduces no error. The bottle was at once shaken thoroughly to insure the equal distribution of the poison. In each experiment except XXXVII Elodea was used.

The acceleration is rather great, considering the dilution; this is possibly due to the fact that the plants had been unusually long in the laboratory, and were respiring very slowly. The

TABLE II.

January 3. To test $\frac{M}{4000}ZnSO_4$ 100 cc baryta water = 12.32 cc $\frac{M}{100}$ acid.

Time	Experiment		Control	
	Titre	cc. N. per hour	Titre	cc. N. per hour
10:16–11:16	.....	.....	12.20	0.012
11:16–12:16	12.20	0.012	12.20	0.012
12:16– 1:52	12.15	0.011	12.18	0.009
1:52	9.5 cc $\frac{M}{100}$ $ZnSO_4$ put into 370 cc in exp. bottle, making $\frac{M}{4000}$.			
1:52– 3:04	12.05	0.022	12.20	0.010
3:04– 4:04	12.10	0.022	12.20	0.012
4:04– 5:10	12.10	0.020	12.20	0.011
5:10– 7:10	11.90	0.021	12.12	0.010
7:10– 9:30	11.85	0.020	12.10	0.009
9:30–10:54 (13.4 hours)	10.05	0.017	10.85	0.011
10:54– 2:36	11.70	0.018	12.00	0.009
2:36	Control given same dose of $ZnSO_4$.			
2:36– 5:00	11.80	0.023	11.85	0.020

great variation in the length of the intervals between the tests is a much more severe test of my method and apparatus than making observations regularly, say every hour or two hours, would be.

The next experiment shows a parallel use of double-distilled and tap water; the evolution of CO_2 is hastened slightly more from the latter.

TABLE III.

January 6. To test $\frac{M}{8000}ZnSO_4$. Double-distilled water in experiment bottle, tap water in control. Result in cc. N. per hour.

Time	Experiment	Control
9:33–10:39	0.015	0.020
10:39–11:51	0.022	0.022
11:51	$\frac{M}{8000}ZnSO_4$ in both bottles.	
11:51–1:51	0.024	0.034
1:51–4:51	0.025	0.036
4:51–7:45	0.025	0.032
7:45–9:47 (14 hours)	0.020	0.023

In the next experiment the difference between the tap water and the double-distilled water is doubtful. When it happened I

ascribed the greater evolution of CO_2 from the former to imperfect distribution of the $ZnSO_4$.

TABLE IV.

January 10. To test $\frac{M}{16000}ZnSO_4$. Double-distilled water in experiment bottle, tap water in control. Results in cc. N. per hour.

Time	Experiment	Control
10:37–12:38	0.027	0.027
12:38– 2:08	0.027	0.027
2:08– 3:26	0.027	0.023
3:26 $\frac{M}{16000}ZnSO_4$	in both bottles.	
3:26– 4:50	0.023	0.043
4:50– 5:50	0.027	0.035
5:50– 8:33	0.027	0.030
8:33–10:03	0.021	0.027
10:03–12:03 (14 hours)	0.028	0.028

The conclusion from this experiment is that $\frac{M}{16000}ZnSO_4$ exerts no appreciable stimulation.

We shall now take up the experiments with more concentrated $ZnSO_4$.

TABLE V.

December 30. Test of $\frac{M}{1143}ZnSO_4$.

Time	Experiment	Control
11:40–12:40	0.025	0.023
12:40– 1:46	0.027	0.027
1:46– 2:46	0.025	0.025
2:46 $\frac{M}{1143}ZnSO_4$	in exp. bottle.	
2:46– 3:46	0.040	0.025
3:46– 4:46	0.038	0.025
4:46– 5:46	0.040	0.025
5:46– 7:46	0.035	0.025

In the remaining experiments the control will be omitted from the report, when it is a mere list of uniform figures.

TABLE VI.

December 17. Test of $\frac{M}{100}$ $ZnSO_4$.

Time	Experiment	Remarks
11 : 52–1 : 52	0.042	
1 : 52–2 : 52	0.040	
2 : 52 $\frac{M}{100}$	$ZnSO_4$ in	exp. bottle.
2 : 52–3 : 52	0.430	The water was poured from both botties and boiled, and the CO_2 collected; the excess from the exp. bottle over that from the control was
	0.320	
Total CO_2 in first hour	0.750	A similar treatment another hour with fresh tap water showed
Total CO_2, second hour	0.665	
Total CO_2, third hour	0.550	

After the third hour the plants were put into water, and were alive but unsound the next morning.

TABLE VII.

December 18. Test of $\frac{M}{50}$ $ZnSO_4$.

Time	Experiment	Remarks
9 : 35–11 : 35	0.033	
11 : 35–12 : 35	0.030	
12 : 35– 2 : 53	0.033	
2 : 53 $\frac{M}{50}$	$ZnSO_4$ in	exp. bottle.
2 : 53– 3 : 53	0.490	The CO_2 was driven off as in the last exp.
Excess from exp.	0.300	
Total CO_2	0.790	

The preceding experiments were all performed at 19°–21° C. The temperature for the next one was 28°–29° C.

TABLE VIII.

December 16. Test of $\frac{M}{50}$ $ZnSO_4$.

Time	Experiment	Remarks
9 : 36–11 : 42	0.045	
11 : 42– 1 : 42	0.045	
1 : 42 $\frac{M}{50}$	$ZnSO_4$ in	exp. bottle.
1 : 42– 2 : 42	1.000	The CO_2 driven from both bottles.
Excess CO_2 from exp.	0.160	
Total CO_2	1.160	

In the experiments with $\frac{M}{50}$, $\frac{M}{100}$, and $\frac{M}{200}$ it was 10–15 minutes before the precipitation of $BaCO_3$ was apparent; then it became very rapid at once.

The bare end-results of some experiments at higher temperatures will be sufficient.

TABLE IX.

December 13. Test of $\frac{M}{100}ZnSO_4$ at 37.5° C.

Time		Experiment	Remarks
2:12–3:12		0.060	
3:12	$\frac{M}{100}$	$ZnSO_4$ in	exp. bottle.
3:12–4:12		0.800	Including excess CO_2 from exp. bottle
Total CO_2		0.925	

The plants were put into water and remained alive.

TABLE X.

December 12. Test of $\frac{M}{200}ZnSO_4$ at 37° C.

Time		Experiment
10:05–2:11		0.088
2:11	$\frac{M}{200}$	$ZnSO_4$ in exp. bottle.
2:11–3:11		0.815
Total CO_2		1.315

TABLE XI.

December 9. Test of $\frac{M}{500}ZnSO_4$ at 39.5° C.

Time		Experiment
2:05–4:05		0.087
4:05	$\frac{M}{500}$	$ZnSO_4$ in exp. bottle.
4:05–5:00		0.743
5:00–6:30		0.627

TABLE XII.

December 4. Test of $\frac{M}{1000}$ $ZnSO_4$ at 36° C.

Time	Experiment
3:41– 5:32	0.109
8:10 $\frac{M}{1000}$	$ZnSO_4$ in exp. bottle.
8:10–10:10	0.207

TABLE XIII.

Temp.	Dilution	Increment
28° C.	50	2480
19	50	2290
19	100	1775
37.5	100	1440
37	200	1390
39.5	500	800
36	1000	90
19	1143	60
19	4000	100
19	8000	30
19	16000	0

If the results of these experiments with zinc are roughly summed up for comparison, it will be seen that the high acceleration by $\frac{M}{4000}$ presents the only exception to the rule that the more zinc applied, the more CO_2 is driven off. The figures here are the per cent. increment of CO_2 evolved after poisoning. The numerator (M) of the fractions is omitted.

The experiments on the influence of copper will be taken up next. The temperature in all of these was in the neighborhood of 20° C.

TABLE XIV.

January 20. Test of $\frac{M}{80000}$ $CuSO_4$.

Time	Experiment	Control
10:08–3:55	0.030	
3:55 $\frac{M}{80000}$	$CuSO_4$ in exp. bottle.	
3:55–5:01	0.030	0.030
5:01–7:16	0.027	0.027
7:35	Same dose given to control.	
7:35–8:36	0.031	0.030

$\frac{M}{80000}$ $CuSO_4$ is then without demonstrable influence on the respiration.

TABLE XV.

January 15. Test of $\frac{M}{40000}$ $CuSO_4$.

Time	Experiment
8:45–10:27	0.029
10:27–12:27	0.032
12·27– 2:15	0.027
2:15 $\frac{M}{40000}$ $CuSO_4$	in exp. bottle
2:15– 3:15	0.039
3:15– 5:27	0.049
5:27–11:27	0.051
11:27–10:32	0.044
10:32– 5:02	0.042
5:02– 9:38	0.044

TABLE XVI.

January 13. Test of $\frac{M}{20000}$ $CuSO_4$.

Time	Experiment
11:46–1:16	0.041
1:16–2:28	0.042
2:28–3:46	0.043
3:46–4:52	0.042
4:52 $\frac{M}{20000}$ $CuSO_4$	in exp. bottle.
4:52–5:52	0.073
5:52–7:52	0.067
7:52–9:52	0.072
9:52–9:52(12hrs.)	0.062

The record in table XV is given for the entire period of observation. It should be said that from most of the tables both ends have been omitted, the published record covering the time more immediately before and after poisoning.

Table XVI shows less CO_2 was evolved toward the end of the experiment, but the material remained alive.

The plants were left in water over night; but few cells were alive the next morning.

TABLE XVII.

December 19. Test of $\frac{M}{10000}$ $CuSO_4$.

Time	Experiment
11:38–2:44	0.034
2:44 $\frac{M}{10000}$ $CuSO_4$	in exp. bottle.
2:44–3:44	0.100
Exc. CO_2 in water of exp. bottle	0.010
Total CO_2	0.110

TABLE XVIII.

December 20. Test of $\frac{M}{5000}$ and $\frac{M}{2000}$ $CuSO_4$, there being no control.

Time	Experiment A	Experiment B
10:00–2:12	0.040	0.038
2:12 $\frac{M}{5000}$ $CuSO_4$	in exp. A bottle.	$\frac{M}{2000}$ in exp. B bottle.
2:12–3:12	0.275	0.335
Total CO_2	0.320	0.435

The CO_2 was driven from both bottles, and the estimated content at the beginning of the hour subtracted; the remainder added to that found by titration.

Both bottles were treated in the same way another hour, with practically the same result. After the first hour most cells were alive in both bottles; but after two hours the plants of exp. B were practically dead.

The result of this experiment made it appear exceedingly probable that CO_2 was evolved after death under the influence of copper. The next two experiments show that this is the case.

TABLE XIX.

December 26. Test of $\frac{M}{2000}$ $CuSO_4$. Plants boiled for twenty minutes in distilled water; then cooled and washed until no CO_2 came off.

Time	Experiment
3:39–4:51	0.000
4:51 $\frac{M}{2000}CuSO_4$	in bottle.
4:51–5:57	0.082
5:57–7:39	0.029
4:51–7:39 (total CO_2)	0.140

TABLE XX.

January 9. Test of $\frac{M}{1167}$ $CuSO_4$. This material was boiled twice in double-distilled water.

Time	Experiment
5:27–6:27	0.007
6:27 $\frac{M}{1167}$ $CuSO_4$	in exp. bottle.
6:27–7:33	0.429

This raised the question as to whether or not Zn might act in the same way on boiled Elodea. Experiment shows that it does.

These results were construed as proving that dead "protoplasm" could be caused to evolve CO_2 by the action of Cu and Zn. As a matter of curiosity I made a similar experiment, using $\frac{M}{1000}$ $CuSO_4$ on peptone (in distilled water); no CO_2, or at most a trace, was evolved.

TABLE XXI.

December 28. Test of $\frac{M}{100}$ $ZnSO_4$. The material was boiled under suction, and washed until no CO_2 came off.

Time	Experiment
8:53–9:53	0.000
10:04 $\frac{M}{100}$ $ZnSO_4$	in bottle.
10:04–11:04	0.020
11:04–12:22 (12.3 hrs.)	0.004
Total CO_2 evolved	0.070

The results of the experiments with copper on live plants are summarized here, in the form explained in connection with the similar table on zinc:

TABLE XXII.

Dilution	Acceleration, Per Cent	Dilution	Acceleration, Per Cent
2000	1045	20000	52
5000	700	40000	47
10000	224	80000	0

The next table shows the action of several concentrations of mercury.

TABLE XXIII.

January 23. Tests of $HgCl_2$.

Time	Experiment	Control
10:28–2:04	0.029	0.033
2:04 $\frac{M}{160000}$	$HgCl_2$ in exp. bottle.	
2:04–7:46	0.035	0.027
7:46 $\frac{M}{80000}$	$HgCl_2$ in control bottle.	
7:46–11:34	0.037	0.039
11:34–11:16 (11.7 hrs.)	0.027	0.032
11:16 A. M. Exp. alive	and sound. Control unsound.	mostly alive,
1:58 P. M. $\frac{M}{10000}$	$HgCl_2$ in exp. bottle.	$\frac{M}{1000}$ in control bottle.
1:58–2:58	0.235	0.685
2:58 Exp. culture	practically dead.	Control dead.

The solutions were poured off to determine the CO_2 in them, and to investigate the post-mortal "respiration" similar solutions made up with tap water were put on the dead Elodea in the bottles. This was followed by practically the same evolution of CO_2 as when the solutions were first applied; which seemed to show that the substance from which the CO_2 was driven off was not exhausted enough to interfere with the reaction. In this connection it was assumed that the evolution of CO_2 gradually slackened under the influence of an individual dose of poison because the mercury entered into combination and ceased to act. The material was then devoted to a determination of how much CO_2 might be driven from it by an indefinitely repeated renewal of the dose of $HgCl_2$. When this had gone on long enough to become monotonous, I varied it by applying the same amount of $HgCl_2$ in less water, making it more

concentrated. *Less* CO_2 was evolved. I then put 700^{cc} of tap water, without Elodea, in each bottle, and gave it the dose which the Elodea and water had been receiving, with the same result. The $HgCl_2$ applied was:

Exp. bottle, 0.7^{cc} $\frac{M}{10}$ Control, 7.0^{cc} $\frac{M}{10}$.

Total CO_2 evolved in 24 hrs. - 0.535^{cc} N. - 2.370^{cc} Normal.
The CO_2 which can be washed from seven hundred cubic centimeters of tap (lake) water varies, but is less than 0.310^{cc} N. - - 0.310^{cc} N., leaving as result of the $HgCl_2$ at least - 0.225^{cc} N. - 2.060^{cc} N., which is more in both cases than the equivalent of the $HgCl_2$ applied.

Evidently no conclusions can be drawn as to the respiration of Elodea, dead or alive, from work with Hg in the presence of tap water. I therefore washed a lot of Elodea very thoroughly in double distilled water for the next experiment.

TABLE XXIV.

March 7. Tests of $HgCl_2$.

Time	Experiment	Control
11:09–3:39	0.070	0.059
3:39 $\frac{M}{80000}$	$HgCl_2$ in exp.	bottle.
3:39–4:39	0.095	0.058
4:39–6:33	0.076	0.059
6:33 $\frac{M}{1000}$ $HgCl_2$ in exp. run through wa	bottle. Plants re	moved from control, and air ter to wash it.
6:33–10:24 (15.85 hrs.)	0.530	(Total CO_2), 0.110^{cc} N
10:24–11:37	.....	(Total) 0.012
11:38 $\frac{M}{80000}$	$HgCl_2$ in con	trol bottle.
11:38–12:40	.....	(Total) 0.060
12:40 $\frac{M}{1000}$	$HgCl_2$ in con	trol bottle.
12:40– 8:00		(Total) 0.160^{cc} N

The last part of this experiment, with the water in which the control plants had stood, shows that CO_2 is driven from substances, presumably carbonates, as of lime, passed from the plants into the water. The evolution of CO_2 caused by $\frac{M}{1000}$ $HgCl_2$ was less excessive than when the plants were present; this I do not ascribe to a reaction with the proteid, but rather to the presence of the cell sap. The difference is doubtless because of the limited amount of carbonates which had passed

from the plants to the water outside. The experiment as a whole shows that no necessarily valid conclusions can be drawn as to the stimulation of the respiration of Elodea with $HgCl_2$, even using the purest distilled water.

The significance of the observations on the influence of Zn and Cu was immediately in doubt. Acting on the suggestion derived from the similar effect of $HgCl_2$ on tap water and on distilled water after the Elodea had stood in it, I used tap water with Zn and Cu, so that the reaction, if any, should be more considerable.

TABLE XXV.

March 9. Action of Zn and Cu on tap water.

Time	Experiment	Control
12:23–1:23	0.005	0.010
1:23 $\frac{M}{1000}$ $ZnSO_4$ in exp. bottle.	$\frac{M}{10000}$	$CuSO_4$ in con.
1:23–2:25	0.150	0.052
2:25 Exp. stopped. $\frac{M}{1000}$ $CuSO_4$ in control bottle.		
2:25–3:25		0.645

These results approach what I got with the same "stimulants" with Elodea in the water.

A test of the apparent action of $AgNO_3$ on the respiration was followed immediately by one with tap water.

TABLE XXVI.

May 1. Test of $AgNO_3$.

Time	Experiment
8:44–1:45	0.042
1:45 $\frac{M}{40000}$ $AgNO_3$ in exp. bottle.	
1:45–2:45	0.130
2:45–3:45	0.095
Tap water then used, without any plants.	
5:34–7:04	0.037
7:04 $\frac{N}{10000}$ $AgNO_3$ in bottle	
7:04–8:04	0.080

This is just near enough to the result with Elodea to rob the latter result of significance as to the respiration.

In another test of the action of $AgNO_3$ on tap water, the water was boiled and cooled with a stream of CO_2-free air passing through it. It was poured into another bottle and then dosed with $AgNO_3$, which drove off only a trace of CO_2. The difference between this and previous experi-

ments with boiled water must have been that the precipitated carbonate was gotten rid of by changing bottles.

$NiCl_2$ was tested similarly to $AgNO_3$.

The acceleration during the first two hours is decidedly more considerable with the tap water than with the Elodea. The rather rapid decrease, while the Elodea is practically constant, might indicate that the effect on the latter is on the proteid, but does not necessarily point that way, as it might merely be because the salts in the sap are not acted on at once.

TABLE XXVII.

May 13. Test of $NiCl_2$. The experiment bottle contains Elodea in 400 cc "Neptune" (a triple-distilled commercial water). The control bottle contains 400 cc tap water.

Time		Experiment	Control
11:05–12:59		0.027	0.003
12:59	$\frac{M}{1000}$	$NiCl_2$ in both	bottles.
12:59– 2:59		0.035	0.026
2:59– 6:23		0.034	0.018

I deemed it not worth while to test the action of some other poisons on Elodea, since, as table XXVIII shows, they all drive CO_2 from tap water.

I have been assuming that the cell sap contains salts like those in the tap water, from which CO_2 can be driven by the poisons applied. This cannot well be doubted; still it seemed desirable to prove it, if possible, by direct experiment. For this purpose I crushed a mass of Elodea from which I should say the CO_2 evolved at the temperature of the experiment could not possibly have been in excess of 0.060 cc N per hour. The sap was squeezed out and the material washed and squeezed again. Of course the plants were most thoroughly washed with distilled water before crushing. The sap was then diluted to 150 cc, and placed in the "control" bottle, while the

TABLE XXVIII.

May 2 and 3. The subject of each of these tests was 400 cc tap water.

Time		Experiment
2:36– 6:06		0.003
6:06	$\frac{M}{100}$ $CoCl_2$ in bottle.	
6:06– 7:21		0.144
8:10– 9:16		0.000
9:16	$\frac{N}{100}$ HCl in bottle.	
9:16–10:22		1.677
10:18–12:52		0.018
12:52	$\frac{M}{100}$ $Pb(NO_3)_2$ in bottle.	
12:52– 2:20		0.776
6:40– 8:20		0.003
8:20	$\frac{M}{1000}$ $Cd(NO_3)_2$ in bottle.	
8:20– 9:26		0.341

"experiment" bottle contained rather less Elodea, uninjured, in 150cc distilled water. The sap was extracted and *filtered* during the evening, and evolved a great deal of CO_2 during the night. The record begins the next morning.

This shows an acceleration of the evolution of CO_2 from the sap, caused by the cadmium salt; also from the sound plants, but not quite as much during the one hour of the action of the cadmium.

TABLE XXIX.

May 23. "Respiration" by sap.

Time		Experiment	Control
9:40–1:22		0.040	0.261
A slight precipitate in the sap caused me to refilter it.			
1:40–6:34		0.046	0.155
6:34	$\frac{M}{1000}$ $Cd(NO_3)_2$ in both bottles.		
6:34–7:34		0.085	0.310

But the most remarkable thing about this experiment was the great evolution of CO_2 from the filtrate. The filtration seemed thorough both times, and after the second no precipitate could be detected before the cadmium was put in; afterward a very slight one was formed. The filtrate was colored and opalescent from the start. It is as impossible to treat the influence of cadmium on the evolution of CO_2 from the sap as depending on the carbonates in the latter as to suppose that the action of copper on the sound plants depends on the protoplasm. If there are processes going on in the sap which lead to the freeing of CO_2, the cadmium may very well act on these processes. By the duration and amount of this evolution the possibility of its being an inorganic reaction is precluded. It suggests very strikingly the accelerated respiration resulting from mechanical injuries, on which we are well informed by the work of Stich[45] and Richards.[46] But nothing hitherto known would indicate that there might be such a reaction by filtered sap. An identical performance observed by Hahn[47] in the sap of the spadix of

[45] STICH, Die Athmung der Pflanzen bei verminderter Sauerstoffspannung und bei Verletzungen. Flora **74**: 1–57. 1891.

[46] H. M. RICHARDS, The respiration of wounded plants. Annals of Botany **10**: 531–582. 1896.

[47] M. HAHN, Chemische Vorgänge im zellfreien Gewebsaft von *Arum maculatum*. Ber. Deutsche Chem. Gesells. **33**: 3555–3560. 1900.

Arum did not suggest that the "respiration" might be abnormally vigorous, as the subject was chosen for its normally intense respiration. Hahn determined that a feature of the respiration by the Arum sap was the rapid consumption of sugar. His paper also discusses briefly the enzymes likely to be concerned. So far as can now be seen, we have here a performance which does not differ from respiration in the materials used, nor in the products, and is stimulated in the same way by mechanical violence and probably by poison, but every substance concerned in which passes through filter paper.

Enough of these tables on the action of the more fatal metallic poisons have been presented so that I anticipate that no other botanist will be attracted to the field as a promising one for conclusive work on respiration, or will imagine that a control of similar plants insures the validity of the results. The tap water experiment was a fortunate accident, where the utmost care would never have discovered the truth. It is very probable that the real respiration is accelerated by these poisons. This is indicated, for instance, in tables II and XV by the long continuance of the higher rate of respiration, and it is made more credible by the probably analogous action of K and Na still to be described.

The action of the poisons on the salts in the cell sap is not without interest in itself. The CO_2 comes ultimately from respiration; what effect freeing it may have on the respiration is problematical. In the other direction, it would seem that the reaction of the sap and the poison might protect the proteid, not of that cell, but of others. This can hardly hold good for as violent a poison as silver, but must of weaker ones, the trace of which remaining in solution would be harmless. Silver will kill Elodea in the presence of more than its equivalent of NaCl; yet I have found that tadpoles acclimated to rather strong NaCl and then thoroughly washed possess a limited immunity to silver poisoning.

There is a good general parallel between the toxicity of the various metals and their power to decompose carbonates, if that is a proper expression for the expulsion of CO_2 from the cell

sap and tap water. This is conspicuously true of the three metals I have studied most thoroughly, Hg, Cu, and Zn; the more toxic the metal, the weaker the solution required to set free measureable CO_2. But this parallel is too hazardous to be dwelt upon. It appears also from the limited data at hand that the power to decompose carbonates is disposed to be parallel to the power to accelerate growth; for instance, Zn is very vigorous in proportion to its toxicity in both respects. The power to set free CO_2 is also proportional in general to the bleaching power of the different metals, as demonstrated by the solutions left with Elodea in them after the tests for toxicity.

Having found no strong metallic poison which did not drive CO_2 from the tap water, I wondered if other poisons might possess the same power. The first tried were antipyrin and iodin, both of which Jacobi found to accelerate respiration. I used such concentrations as he had done.

TABLE XXX.

May 12. Test of iodin. Experiment bottle contains Elodea in 400^{cc} "Neptune" water. Control is 400^{cc} tap water. The air after passing each runs through a small bottle containing 100^{cc} aq. dest. in which is more iodin than will dissolve.

Time	Experiment	Control
11:19–3:13	0.037	0.004
3:13 The iodin water	poured into the	other bottles.
3:13–6:13	0.068	0.002
6:13–7:43	0.060	0.000

TABLE XXXI.

May 10. Test of antipyrin. Experiment and control are same as in XXX.

Time	Experiment	Control
10:59–3:49	0.030	0.002
3:49 0.25 % antipyrin in both	bottles.	
3:49– 5:59	0.047	0.002
5:59– 7:59	0.050	0.007
7:59– 9:32 (13.55^h)	0.047	0.005
9:32–11:32	0.045	0.000
11:58 $\frac{N}{100}$ HCl in both	bottles.	
11:58– 2:22 (total O_2)	0.925	1.805

Both iodin and antipyrin accelerate the evolution of CO_2 from the Elodea, but not from the tap water. Their action must be on the the protoplasm. The acceleration observed was a shade greater than Jacobi's result with the same substances.

An experiment with potassium cyanid may be inserted here. The reason for performing it was the regard in which KCN is held by animal physiologists as a substance inhibiting respiration. The evidence for this rests, largely at least, on its preventing the consumption of oxygen, so that in KCN poisoning the blood retains its arterial color (its other effect in interfering with the carrying of the O by the blood being irrelevant here). I have made two tests of the evolution of CO_2 under the influence of KCN, one of which is reported here. Neither of them has the measure of quantitative exactness I could desire, but the apparent acceleration was so great it is hardly possible that it should have been an error.

TABLE XXXII.

January 22. Test of KCN. No control.

Time	Experiment
10:54–3:54 3:54 $\frac{N}{100}$ KCN 3:56–4:56	0.048 in bottle.

The alkalinity of KCN prevented the escape of more than a trace of CO_2. To determine the CO_2 then the KCN solution was made slightly acid with H_2SO_4, and the CN precipitated with $AgNO_3$. It was then boiled.

Total CO_2 - - - 0.899^{cc} N.

As a control, 400^{cc} $\frac{N}{100}$ KCN (same solution) treated in same way. The CO_2 from it was - - - - - 0.208^{cc} N,
or for 500^{cc} - - - 0.260, leaving as the CO_2 from respiration in the experiment - - - - 0.639^{cc} N.

This result, with the evidence that oxidation is hindered by KCN, suggests forcibly that it is a substance which acts on "normal" but not on "intramolecular" respiration, which would amount to a proof for the already well supported theory that the evolution of CO_2 and the taking on of O are distinct activities of the plant; the latter, when it occurs, being dependent on the former, instead of *vice versa*. The action of KCN will well repay more study, whatever it may show, but I have had no time to follow it up.

The work on chemical stimulants was concluded with tests of some of the common mineral foods. Of these, calcium nitrate caused a more active evolution of CO_2 from Elodea, but as it was found to have the same effect on tap water, its action on the plant was of questionable nature, and the table showing its effect is omitted. Sodium chlorid and nitrate, and potassium chlorid, nitrate, sulfate, and iodid were all tested as to their action on tap water, from which none of them caused any escape of CO_2. To report the individual experiments showing this would be superfluous. Excepting a number of them which illustrate an altogether novel point in connection with the death of the plants, the individual tables of the results of the application of these salts can also be dispensed with, and their places will be taken by a single table showing the per cent. of acceleration of respiration. This per cent. is computed from what seems to me to be so much of the results of the experiments as represent the action of the salts on sound, unacclimated plants.

When any of these salts were applied to the plants in concentrations of $\frac{N}{20}$ to $\frac{N}{5}$ there was a prompt increase in the rate of respiration. This quickened rate remained constant in most of the experiments for a period of from twelve hours to more than a day; then it fell steadily or rose rather abruptly. The per cent. of acceleration is figured from the steady rate following the application of the salt, as compared with the preceding hours. The length of this period of uniformly accelerated respiration depended on the condition of the Elodea, on the nature of the salt and its concentration, and on the temperature, being shorter at higher temperatures.

The desired concentration of these salts was near enough to their limit of solubility so that applying them like the strong poisons would have introduced a possible source of large error in the CO_2 dissolved or soluble in the solution applied. This was avoided by the method employed with iodin (table XXX), letting the CO_2-laden air from each Elodea culture pass through another bottle containing the salt to be applied. Thus, if I had 2N KCl, and wished to test $\frac{N}{10}$, the Elodea was placed

in 400cc water, and the smaller bottle contained 22cc of the $\frac{N}{10}$ solution, and water to 40cc. The CO_2 content of the two bottles must have been practically the same when air had been passing through them over night.

TABLE XXXIII.

Salt	$\frac{N}{20}$	$\frac{N}{10}$	$\frac{N}{5}$
NaCl	29%	..	35%
$NaNO_3$	..	34%	58 (too high; cf. XXXV)
	..	..	32
KCl	41	42	58
	29.4	48.7	52
KNO_3	39	40.4	62
	36.4	..	61
K_2SO_4	..	31	..

A single comparison of KNO_3 and KI, both $\frac{N}{10}$, showed the same acceleration for eighteen hours at about 21°C., after which the KI material took a considerable lead and was in large part dead when the experiment ended.

It appears from this summary of results on K and Na, that the former is decidedly the stronger stimulant. Jacobi (p. 302) reports a much greater acceleration by $\frac{N}{20}$ NaCl than by $\frac{N}{20}$ KCl; but in six experiments, only part of which are represented in the above table, in which KCl or KNO_3 was in one bottle and the same concentration of the corresponding Na salt in the other, I have found no single instance in which the K salt failed to produce the greater effect. Kosiński (p. 141), at the other extreme, concludes that while KNO_3 and K_2SO_4 accelerate the respiration of Aspergillus, NaCl does not do so at all. My results on the respiration harmonize perfectly with the greater toxicity of K. True[48] rates the relative toxicity of K and Na to Spirogyra at 10:6. It seems to be about the same to Elodea.

It has been found by a number of observers that chlorids

[48] R. H. TRUE, The physiological action of certain plasmolysing agents. BOT. GAZ. **26**: 407–416. 1898.

and nitrates of the same metals have the same toxicity, and the relatively few contrary statements do not bear the stamp of great probability. Coupin, for instance, rates the relative effectiveness of LiCl and $LiNO_3$ as 12:5, and that of $MnCl_2$ and $Mn(NO_3)_2$ as 1 : 13. Such a result is too surprising not to be doubted until there is more evidence for it. That chlorids and nitrates of the nutrient base often act differently in experiments of long duration, when used as fertilizers, is partly due to changes in the salts themselves. But working with salts whose base acted mildly enough so that concentrations even strong enough to cause plasmolysis could be used, it would have been possible to detect differences in the toxic or stimulating power of Cl or NO_3 ions too insignificant to suggest themselves at greater dilutions. Taken altogether, the NO_3 ion has been a shade the more active in my experiments; but there is no emphatic or constant difference in the stimulating action, in the effect on the turgor, or in the toxicity.

Up to $\frac{M}{5}$, the stronger the salt, the greater the stimulation, but the added stimulation by no means remains proportional to the concentration; which is only another illustration of the general rule that the less of any food is present, the greater its efficiency in proportion to the amount.

I pass over any discussion of the probable mode of action of K and Na, whether as food or stimulant, because in the present state of our knowledge of the details of metabolism any such distinction in the case of essential food elements is difficult in words, and imaginary in practice.

The Elodea would always plasmolyze in 2 per cent. KNO_3 when the experiments began. In all the experiments then in which a salt was applied in the concentration of $\frac{N}{5}$ the cells must have been slightly plasmolyzed for a time. I was somewhat surprised that in such a case the extraction of water, as a purely physical process, did not operate to depress the respiration, but it seemed not to, as the acceleration was manifest from the time the salt was applied. When still stronger solutions are used, the physical action of extracting water and compres-

sing the protoplast predominates over the chemical stimulation, and the respiration sinks below normal.

TABLE XXIV.

June 4. Test of $\frac{2N}{5}$ KNO_3 and KCl. Exp. is Elodea in 225^{cc} dist. H_2O. Small bottle has 150^{cc} $\frac{N}{1}$ KNO_3. Control Elodea in 225^{cc} dist. H_2O. Small bottle has 150^{cc} $\frac{N}{1}$ KCl.

Time	Experiment	Control
10:15– 6:09	0.073	0.070
6:09 Bottles	poured together.	
6:09– 8:27	0.063	0.059
8:27–10:39	0.064	0.057
10:39– 7:21 (8.7) hrs.	0.044	0.045
7:21– 2:09	0.052	0.077
2:09–10:09	0.140	0.144

The low figures for the third period after applying the salt are partly due to a fall of 1.3° C. in temp.

The very rapid increase in the evolution of CO_2 occurred about as long after the application of the salt as was to have been expected with a solution but half as strong, from which it appears probable that the physical action of the salt has tended to protect the plant. The case is roughly analogous to those of the seeds of Lepidium[49] and the sporocarp of Marsilea,[50] which retain their vitality indefinitely in very strong alcohol, but succumb quickly if the alcohol contains water enough to soften the coats and make them permeable.

TABLE XXXV.

May 27. Test of $\frac{N}{5}$ $NaNO_3$.

Time	Experiment
6:58–11:52	0.033
11:52 Bottles po	ured together.
11:52–6:22	0.052
10:00 P.M.–10:00 A.M.	0.038
10:00–6:00 (8 hours.)	0.087
6:00 P.M., May 28	Tested as to
turgor and	found dead.
6:15–9:45	0.107

The exceptional acceleration of 58 per cent. by $NaNO_3$ (table XXXIII) comes from computing it from the first 6.5 hours of the salt's action. If 18 hours had been included it would have been only 30 per cent.

It remains to present a few of the experiments with K and Na fully enough to illustrate, as the last table does, the final rise of the curve of respiration, usually about a day after the application of the salt.

[49] F. NOBBE, Handbuch der Samenkunde 116. Berlin. 1876.

[50] C. R. BARNES, Vitality of *Marsilea quadrifolia*. BOT. GAZ. **20**: 229. 1895.

TABLE XXXVI.

May 18. Test of $\frac{N}{5}$ KCl and NaCl.

Time	Exp., KCl	Cont., NaCl
9:55–2:35	0.055	0.054
2:35	Bottles poured together.	
2:35–6:35	0.087	0.073
	Record over night not kept.	
8:36 A. M.–10:36	0.099	0.064
10:36–12:36	0.097	0.071
12:36– 2:36	0.109	0.076
10 P. M.	Almost dead.	Alive.
May 20, 11:00 A. M.	Dead.	Alive; not very unsound.

TABLE XXXVII.

May 20. Test of $\frac{N}{5}$ KNO_3 and $NaNO_3$. Subject, Ceratophyllum.

Time	Exp. KNO_3	Cont., $NaNO_3$
8:35–1:41	0.021	0.0296
1:41	Bottles poured together.	
1:41–8:11	0.034	0.039
8:11–8:41 (12.5 hrs.)	0.057	0.058
8:41–11:41 (May 21)	0.073	0.053
11:41–11:53 (12.2 hrs.)	0.044	0.043

This experiment carried the plants past the point of most excessive combustion. The temperature during it was about 24.6°C.—the highest in any of these experiments.

TABLE XXXVIII.

June 2. Test of $\frac{N}{5}$ KNO_3 and KCl.

Time	Exp., KNO_3	Cont., KCl
8:37–12:43	0.028	0.027
12:43	Bottles poured together.	
12:43–10:43	0.045	0.041
10:43–10:46 A. M.	0.067	0.074
10:46–9:46 (June 3)	0.068	0.078

The plants were "dead" at 10:46 A. M., June 3.

As already mentioned, plants treated with $\frac{N}{10}$ KI showed this phenomenon, but the parallel culture with KNO_3 did not while the experiment lasted.

This excessive evolution of CO_2 is undoubtedly a feature of the death of the plant. It is not easy to fix a time at which it begins, because the cells in a single leaf do not all die together; but it is conspicuous while a very large part of the material is still evidently alive. It continues after the entire material, judged by its appearance under the microscope or by the test of plasmolysis, would be called dead. Two conceivable sources of this CO_2 suggest themselves; it might be allowed to escape by the removal of an obstruction when the protoplasm dies, as the acid in sour leaves gets an opportunity to destroy the chlorophyll; or else its origin is in the protoplasm itself. As we have every reason to suppose, and none to doubt, that CO_2 diffuses readily through the living protoplasm, the first of these suggestions may be dismissed, and we may accept it as a fact that the escape of a large amount of CO_2 is not merely an accompaniment of death, but is a part of death.

If the phenomenon is thus fundamental in the demise of the plant, it must occur under other fatal conditions beside poisoning. In the experiments in which plants were boiled there was an amount of CO_2 evolved for which I was at the time quite unable to account. And I have had several opportunities to observe an increase of apparent respiration as Elodea succumbed to prolonged exposure to too high a temperature. Two of these follow; the first is an extract from the same experiment as table XI, showing the behavior of the control later in the day; during the hours included in table XI the control had been reasonably steady.

TABLE XXXIX.

December 10. Elodea at 39–41° C.

Time	Control
6:30– 8:05	0.087^{cc} N. per hr
8:05– 9:05	0.105
9:05–10:05	0.100
10:05–11:05	0.150
11:05–12:05	0.135
12:05–11:05 (11 hrs.)	0.143
11:05– 1:05	0.117

In the experiment recorded in table XL the rise in the control occurred in time to invalidate the results of the experiment culture.

While I have observed this feature of death only as a result of poisoning and of heat, it appears to me very possible that the

immediate evolution of CO_2 when tubers were cut in Richards's work (*l. c.* 1896, p. 544) should be explained in the same way. CO_2 diffuses through cork so much more readily than does O that a great accumulation of it within the tuber, to be set free from any exposed surface, seems hardly natural. Kolkwitz[51] finds that grain ground to meal, soaked in alcohol, or heated to 100° C., all processes calculated to kill it, still gives off a very appreciable amount of CO_2. The behavior of Elodea sap might point in the same direction, though the consumption of large quantities of sugar, observed by Hahn in in the sap of Arum, demands a different interpretation.

TABLE XL.

December 6. Elodea at 39–41° C.

Time	Control
4:30– 5:30	0.070
5:30– 7:30	0.085
7:30– 9:30	0.097
9:30–11:30	0.110
11:30– 1:30	0.110

The evolution of CO_2, not only as a phase of death, but as a process continuing indefinitely after death, is another question on which I have sought for light. Reinke[52] has said that in the presence of atmospheric O dead seedlings and leaves continue to evolve CO_2 at ordinary temperatures, and his statement that no microorganisms are responsible for the phenomenon ought to be reliable. Schlösing[53] and Berthelot and André[54] have found CO_2 given off at high temperatures, 70–110° C., under the most various conditions. If these observations admitted of general repetition, all of our determinations of dry weights would be proven not to represent the entire solid matter of the plant.

My experiments with Hg, Cu, and Zn, which seemed at first to be the most striking proof of indefinite loss of CO_2 after death, can no longer be regarded as any positive evidence on

[51] R. KOLKWITZ, Ueber die Athmung ruhender Samen. Ber. Deutsch. Bot. Gesells. **19**: 285–287. 1901.

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the subject. The evolution from plants killed by K and Na decreased after they had been dead a few hours. The solubility of CO_2 in water makes my usual method of experimenting inappropriate to the determination of a time when CO_2 may cease to be evolved. I have tried one experiment which proved that if Elodea is left in water and kept at about 90° C. the evolution of CO_2 gradually diminishes, but at the end of four days is still as rapid as in the ordinary respiration of the same plants. As a control the same amount of material was placed in so little water that it became dry within twenty-four hours, and the evolution of CO_2 fell to a trace, without, however, quite ceasing. The material was again wetted and considerable CO_2 was evolved, though less than from the material which had been kept in water. It would appear from this that the usual dry-weight determinations are practically valid, and a number of tests which I have made with seeds show that at most a trace of CO_2 escapes as they dry at 100° C., or even a few degrees higher.

SUMMARY.

The method has been perfected until the results are reliable to one-fiftieth of a milligram.

No poison has been found *not* to act as a stimulant.

Metallic salts drive CO_2 from carbonates in the cell sap. This pseudo-respiration, under the action of strong poisons, is many times as active as the real respiration, and makes the study of the latter impossible.

CO_2 is given off from filtered sap squeezed from Elodea much more rapidly than from the Elodea before injury.

The stimulation by K salts is greater than that by Na salts, in about the proportion of their relative toxicity. No constant difference was found between chlorids and nitrates.

A considerable evolution of CO_2 is a feature of the breaking down of "protoplasm" into mere "proteid," in death.

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THE EMBRYOGENY OF ZAMIA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XLV.

JOHN M. COULTER and CHARLES J. CHAMBERLAIN.

(WITH PLATES VI–VIII)

OUR knowledge of the development of the embryo of Cycadales is very meager, being largely included in Treub's (5) account of *Cycas circinalis* and Ikeno's (8) of *Cycas revoluta*. These two accounts agree in every important particular, and deal chiefly with the development of the proembryo. The following facts were established: the egg nucleus divides, and successive simultaneous divisions give rise to a large number of free nuclei; the cytoplasm of the central region of the egg becomes vacuolate and then completely disorganizes; the remaining cytoplasm becomes parietal, massing somewhat toward the bottom of the egg; in this parietal layer the numerous free nuclei are imbedded, being equidistant from one another and forming usually a single layer except at the base of the egg, where simultaneous nuclear division begins again; later, walls appear, and the proembryo becomes a sac somewhat thickened at base, but with the wall composed of one or at most two layers of cells. This history differed so much from that of Ginkgoales and of Coniferales as known at that time that it seemed to stand somewhat stiffly apart among gymnosperms.

A series of collections of *Zamia floridana* was obtained from southern Florida during the spring and summer of 1902. Some collections consisted only of the ovulate strobili, but in most cases the entire plant was secured. As stated by Webber (11), the ovulate strobili continue in their development for some time after removal from the plant, and we have observed mitotic figures in ovules after the strobilus had been lying in the laboratory for nearly two weeks. Entire plants sent from Florida in June and July were potted, and they continued to develop

quite normally, a large proportion of the ovules becoming seeds with fully formed embryos. The material yielded a fairly complete series of stages from a period somewhat before fertilization to the ripening of the seeds.

The presence of a ventral canal cell among the Cycadales was for some time in question. Strasburger (**2**) seems to have been the first to recognize it in 1876 in *Cycas sphaerica*, and in 1877 Warming (**3**) reported a ventral canal cell in *Ceratozamia robusta*, but soon (**4**) decided that he had been mistaken. In 1884 Treub (**5**) failed to find one in *Cycas circinalis*, and the impression became general that no such cell is formed among Cycadales. In 1896, however, Ikeno (**6**) announced that a ventral canal cell is formed in *Cycas revoluta*, and in a later paper (**8**) he figured and described the mitosis that separates the nuclei of the ventral canal cell and egg. In 1897 Webber (**7**) reported that in Zamia "a small cell is cut off at the apex of the archegonium, which corresponds to the canal cell of Conifers."

In our study of Zamia the mitotic figure was found which gives rise to the nuclei of the egg and ventral canal cell (*fig. 1*). The chromosomes are very slender and inconspicuous, and the spindle is somewhat multipolar. Considering the great size of the central cell, the whole structure is extremely small and might easily escape notice unless well stained. After the mitosis is completed the nucleus of the egg begins to enlarge and to move toward the center of the cell, while the other nucleus becomes smaller and soon disorganizes (*fig. 2*). It will be seen from *fig. 2* that there is no wall between the two nuclei, and we were not able to find any case in which a definite ventral canal cell had been cut off.

The protuberance in which the ventral canal nucleus lies rapidly disorganizes and remains for a time as a more deeply staining mass at the top of the egg. It seems probable that in his first account Warming (**3**) was describing as a ventral canal cell the disorganizing protuberance in which the ventral canal nucleus lies. Ikeno's *fig. 11* (**8**) seems to be almost identical with our *fig. 2*, and although he states that "this portion (the

protuberance) becomes completely separated from the egg cell," it is difficult to see how a wall such as usually separates the ventral canal cell from the egg could be formed after the achromatic figure has disappeared. It seems more likely that here, as in Zamia, the disorganizing protuberance might have been taken for a cell, and Ikeno himself in a brief note at the close of his paper on Ginkgo (10) admits that the wall may be lacking. In Ginkgo, which in so many features resembles the Cycadales, a definite ventral canal cell is separated from the egg by a wall, as figured by Strasburger (1), and the details of the mitosis are described by Ikeno (10), who figures a conspicuous cell plate at the telophase of division.

The Coniferales present some variation in the formation of the ventral canal cell; in most of the cases reported a definite wall being formed between the two nuclei, but in Cephalotaxus (Arnoldi, 9), in Taxodium and Podocarpus (Coker, 12), and in Thuja (Land, 13), no wall is formed. Arnoldi's statement that the ventral canal cell is lacking in the Cupresseae certainly does not hold for the group, and it is doubtful whether such a cell or at least a nucleus representing it is absent in any gymnosperm. It would be of interest to know whether in any of the Cycadales a definite wall is formed between the nuclei of the egg and ventral canal cell. Since such a wall is uniformly present in the bryophytes and pteridophytes, its absence among the Cycadales would have to be regarded as a case of suppression.

Our preparations of the fertilization stages in Zamia merely confirm the very full account recently published by Webber (11).

The immense size of the fertilized egg of Zamia is a matter of surprise to any who are not familiar with the archegonia of Cycadales. The fertilized egg is usually 3^{mm} in length, and its nucleus is plainly visible to the naked eye, often reaching a length of 1000μ, as shown in *fig. 3*, which shows the actual size of the upper portion of the gametophyte with two archegonia.

After fertilization there is a period of free nuclear division. These divisions are simultaneous (*fig. 4*) and follow one another with such rapidity that the nuclei become smaller at each successive division. The first nuclear division was not found in

our preparations. Webber (11) observed the second division and states that the first two divisions occur near the center of the egg, and that the nuclei then become scattered, and that "finally in the first stage of the organization of the embryo form a layer of cells about the periphery of the egg cell." We were able to count the nuclei in the 16-nucleate and 32-nucleate stages, being of course the product of the fourth and fifth simultaneous divisions. The 64-nucleate and 128-nucleate stages were counted approximately. In two cases the mitotic figures of the eighth division, which gives rise to the 256-nucleate stage, were counted with considerable certainty, assuming, as seems safe, that these early divisions are all simultaneous. In both of these series, which consisted of more than fifty sections, from several of which the proembryo had been lost in making the preparations, over one hundred figures were counted. Since the seventh division would show only 64 figures and the ninth division 256, there could hardly be a possibility of mistaking this stage. A section from one of these series is represented in *fig. 4*.

The entire mitotic figure is formed within the nuclear membrane, which does not disappear until the anaphases are reached. The kinoplasmic portions of the figure are highly developed, the polar radiations being particularly conspicuous. The whole figure differs decidedly from the one concerned in the formation of the ventral canal nucleus (*fig. 1*), for in this case the nuclear membrane disappears before the metaphase is reached, and there are no polar radiations whatever; and also from the later divisions in the embryo, in which the nuclear membrane disappears early. That simultaneous divisions cease with the eighth division may be regarded as certain, for numerous preparations of the proembryo just before the formation of the cell wall (*figs. 5, 6*) fail to show even approximately the large number of nuclei (512) which should be found if a ninth division had taken place.

The appearance of the proembryo at the close of free nuclear division, but before the formation of any cell walls, is shown in *figs. 5* and *6*. In both these figures the nuclei are scattered throughout the entire egg, there being no tendency to form a large central vacuole with consequent parietal placing of the

nuclei, as in Cycas. In the stage represented in *fig. 5* the nuclei are more numerous in the lower part of the proembryo, doubtless on account of the settling of some of them. This settling is sometimes very evident, the nuclei being lined up along strands of cytoplasm, which appear almost as definite as bundles of spindle fibers, although they are only such trails as might be caused by nuclei passing rapidly through the cytoplasm. Very similar appearances were noticed in eggs which had been ruptured by the pressure of the razor in cases where the portion containing the archegonia had been cut out previous to placing in the fixing fluid. In these cases the trails were caused by the rapid movement of the cytoplasm toward the point of exit.

It is worthy of note that in most of our preparations of the early stages, including the eighth simultaneous nuclear division (*fig. 4*), the nuclei are nearly all in the lower half of the egg; while in later stages (*figs. 5–10*) the upper portion is never free from nuclei. In this connection it should be noted also that just before the appearance of cell walls (*figs. 5–6*) the number of nuclei is often more than 256, although never so many as 512, the number which would result from a ninth simultaneous division. It seems probable that many of the nuclei in the upper part of the proembryo, which is not to form any part of the embryo proper, are due to irregular or amitotic division. It is certain that the nuclei of this region are irregular in size and often amoeboid in outline. Some of these nuclei may have been due to the entrance of two male cells, one remaining near the apex and dividing. The two large irregular nuclei shown in *fig. 4* suggest this explanation. While the ventral canal nucleus might divide and give rise to nuclei in this region, we have seen nothing which would make such an explanation probable.

Ikeno's (**8**) account indicates that even in the earlier stages of development the embryo of Cycas differs considerably from that of Zamia. In Cycas, as in Zamia, fertilization is followed by a period of free nuclear division, but in *Cycas circinalis* (Treub, **5**) and also in *C. revoluta* (Ikeno, **8**) a large central vacuole is soon formed. According to Ikeno, who gives a more detailed account, the nuclear division near the neck of the

archegonium may be amitotic; after the number of free nuclei has become quite large, the vacuole is formed by the disorganization of the cytoplasm and free nuclei of the central portion of the egg. After the vacuole has become established there remains at the base of the egg a rather dense mass of cytoplasm containing numerous free nuclei, while the cytoplasm in other parts of the egg is reduced to a thin peripheral layer with comparatively few nuclei. At this period free simultaneous nuclear division is resumed in the region at the base of the egg, which is apparently quite sharply marked off (Ikeno, **8**, *fig. 49*), so that there are two rather definite periods of free nuclear division. In Zamia (*figs. 3, 5, 10*) there is only one period of free nuclear division, and no vacuole is formed during these early stages or even after the suspensor has begun to elongate, the free nuclei of the upper portion being scattered throughout the cytoplasm. Even in stages more advanced than that shown in *fig. 10* a vacuole has not yet formed, although the cytoplasm is becoming very scanty in the region which in Cycas is occupied by the large vacuole. Of course in later stages of development (*fig. 11*) the entire region, which in *fig. 10* is occupied by cytoplasm and free nuclei, becomes empty.

In the formation of cell walls also Zamia differs from Cycas. In *Cycas circinalis* walls are formed throughout the entire region occupied by nuclei, while in Zamia the formation of walls is restricted to rather a limited area at the base of the egg. The earlier walls (*fig. 7*) are formed as in the endosperm of those angiosperms in which a period of free nuclear division precedes the formation of cell walls, excepting that in Zamia we have never found more than one nucleus in a cell, as sometimes occurs in angiosperms. At first the cells are all of the same size, but very soon those at the base begin to stain more deeply, and on account of more rapid division become smaller than those above them (*fig. 8*). The differentiation soon becomes quite marked, and the elongating cells of the suspensor can be distinguished easily from those of the embryo proper (*fig. 9*). In the last-cited figure, as well as in *figs. 8* and *10*, it may be seen that just above the definitely walled cells there is a region where

wall formation is indefinite and incomplete, and that beyond this no walls are formed.

The rapid elongation of the suspensor (*figs. 13–16*) forces the embryo down into the endosperm. The resistance is so great that in later stages the base of the embryo is forced upward into the archegonial chamber and is stopped only by the hard seed coat. The suspensor is long and twisted. When straightened out (*fig. 11*) it may be fully 5^{cm} long.

Certain features of the mature embryo may mentioned. The two cotyledons are free at apex and base, but are more or less completely fused in the middle region. The long cotyledons (*fig. 12*) constitute much the larger part of the embryo, the whole axis being comparatively small. The plumule is well developed, several leaf primordia being evident. Several branching mucilage canals extend from the root to the tips of the cotyledons. According to Warming (4) the embryo of Ceratozamia has only one cotyledon, a part of the meristematic apex of the axis becoming differentiated into the single cotyledon and the rest forming the stem tip.

These results with Zamia have enabled us to arrange a suggestive series of gymnosperms as shown by the accompanying diagram (*fig. 17*). In the first series a gradual reduction in the number of free nuclei is shown. In Ginkgo, Cycas(?), and Zamia it would seem that eight successive simultaneous nuclear divisions precede wall formation, resulting in 256 free nuclei. Among the Coniferales there is a sudden drop in the number of free nuclei, but at the same time a diminishing number from 32 to 4, as follows: Taxus 32; Cephalotaxus, Podocarpus, and Taxodium 16; Thuja 8; Pinus 4. While these numbers probably represent the usual condition, the higher numbers are not entirely constant, wall-formation sometimes occurring at an earlier division than usual. For example, in Podocarpus wall-formation may occur after the third division, but usually only after the fourth; while in Taxus wall-formation has never been observed to occur until after the fourth division, and often only after the fifth. Further reduction in the number of free nuclei occurs among the Gnetales, Ephedra sometimes showing only a

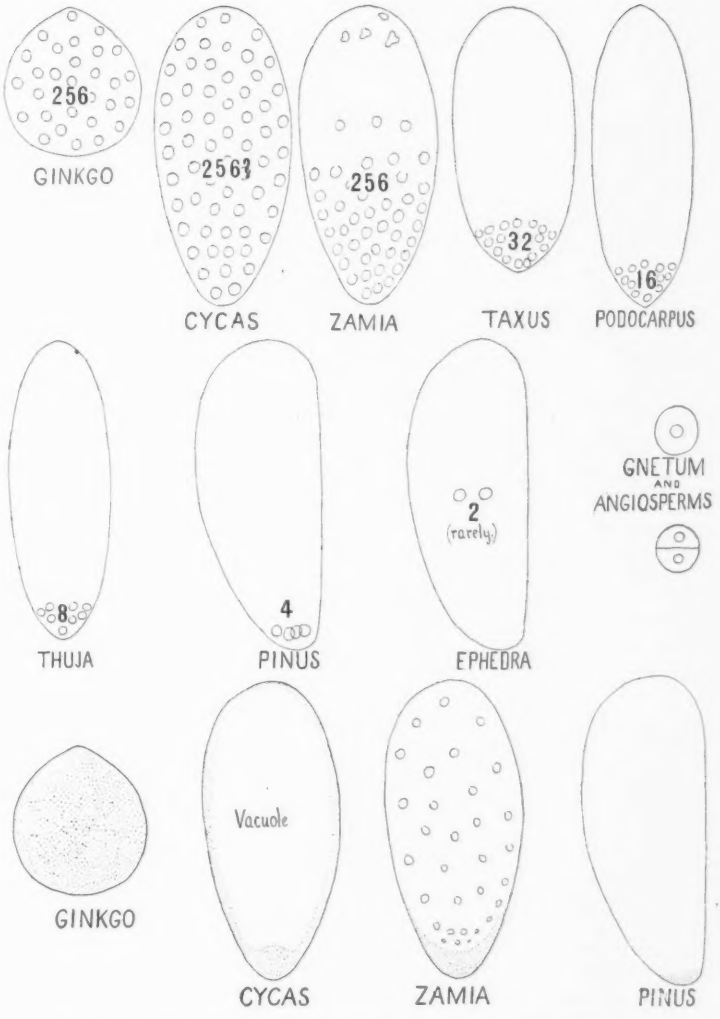

FIG. 17. A series of diagrams to illustrate the extent of free nuclear division and wall-formation; the shaded portions of the last four figures represent the region of wall-formation.

single free nuclear division, resulting in two free nuclei; and in Gnetum and Tumboa no free nuclear division occurs at all. These last-named forms have reached the condition of the embryogeny of angiosperms, in which the first division of the nucleus of the egg is accompanied by the formation of a wall. The gap between Zamia with its 256 free nuclei and Taxus with its 32 may seem great at first sight; but it should be noted that it represents the omission of only two successive divisions, the sixth and seventh. It is entirely possible, therefore, that these missing numbers (64 and 128) may be found among the numerous Cycadales and Coniferales that await investigation.

In the second series shown in the diagram a later stage is presented. In this series Ginkgo is clearly at one extremity with its numerous free nuclei equally distributed, and its wall formation resulting in a proembryo that completely fills the egg. In Cycas the free nuclei do not remain evenly distributed, but there is a massing toward the base of the egg, and most of the remaining nuclei through the formation of a central vacuole pass to the periphery and enter into the formation of a parietal layer. In Zamia wall-formation is still further restricted, appearing only in connection with the basal nuclei. There is also no development of a central vacuole, and hence no parietal placing of free nuclei. In Zamia, therefore, a tissue that fills the sac, as in Ginkgo, or that lines the egg, as in Cycas, is reduced, and its formation is restricted to the basal region, as in Coniferales. In passing from this condition, represented by Zamia, to the condition displayed by the Coniferales, there is a gradual reduction in the number of nuclei that enter into the formation of this basal tissue, and as a result a gradually more definite setting apart of the function of each particular nucleus. For example, in Zamia the suspensor cells are not recognizable until they begin to elongate; in Taxus with its 32 nuclei, and in Cephalotaxus, Podocarpus, and Taxodiun with their 16, there is no setting apart of a distinct suspensor-forming layer; while in Thuja with its 8 nuclei a distinct suspensor-forming layer is recognized, and this definiteness is continued into the 4-nucleate forms.

It would seem to follow from these considerations that the

embryogeny of Ginkgo is the most primitive one among gymnosperms; that the embryogeny of Cycas is more primitive than that of Zamia; that in its embryogeny Zamia approaches more nearly the Coniferales than does Cycas; that such forms as Taxus, Cephalotaxus, Podocarpus, Taxodium, and Thuja show progressive stages of embryogeny from that of Zamia toward that of Pinus; that Ephedra has the most primitive embryogeny among the Gnetales; and that Gnetum and Tumboa resemble the angiosperms in the elimination of free nuclear division from their embryogeny.

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EXPLANATION OF PLATES VI–VIII.

All the figures are from *Zamia floridana*. *Figs. 13–16* are from photomicrographs of rather thick sections. The rest of the figures, except *figs. 3, 11, 12*, are from camera lucida drawings.

FIG. 1. The mitotic figure which gives rise to the nuclei of the egg and the ventral canal cell. × 200.

FIG. 2. A later stage showing the two neck cells (*a*), the ventral canal nucleus (*v*), and the nucleus of the egg (*e*). × 45.

FIG. 3. Upper portion of the gametophyte showing two archegonia; the nucleus of the fertilized egg (*n*) is plainly visible to the naked eye. *Natural size.*

FIG. 4. Free simultaneous nuclear division in the proembryo; the number of mitotic figures in this proembryo is estimated at 128; the two large irregular nuclei at the top may have come from a male cell; the spindle-shaped bodies at the top are probably coagulated food material. × 25.

FIG. 5. Proembryo after simultaneous free nuclear division has ceased; the remains of the blepharoplast (*b*) can still be seen. × 20.

FIG. 6. A stage slightly later than that shown in *fig. 5;* the strands at the bottom seem to be related to the settling of the nuclei. × 20.

FIG. 7. The beginning of wall-formation at the base of the proembryo. × 20.

FIG. 8. Differentiation into suspensor and embryo proper becoming distinguishable. × 30.

FIG. 9. A more advanced stage, the embryo and suspensor being quite definitely outlined; the faint and incomplete septation above the suspensor is also shown. × 50.

FIG. 10. A still later stage; the suspensor has lengthened considerably; no central vacuole has yet been formed, although the cytoplasm in the region occupied by the vacuole in Cycas at this stage and earlier is becoming scanty. × 36.

FIG. 11. Young embryo dissected out from the seed; the suspensor has been pulled out straight. *Natural size.*

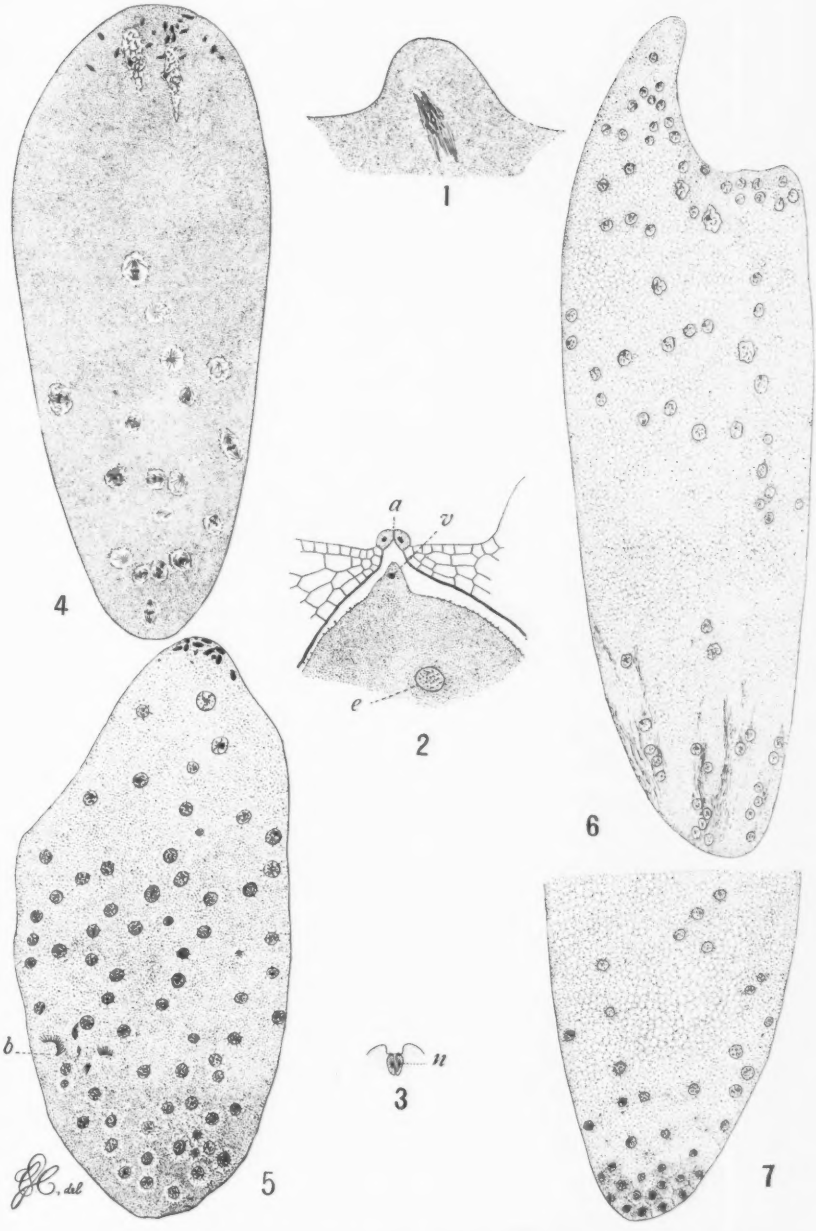
FIG. 12. A nearly mature embryo, showing the two cotyledons and suspensor. *Natural size.*

FIG. 13. Upper part of gametophyte showing embryo and characteristic cavity formed by disintegration of surrounding tissues. × 14.

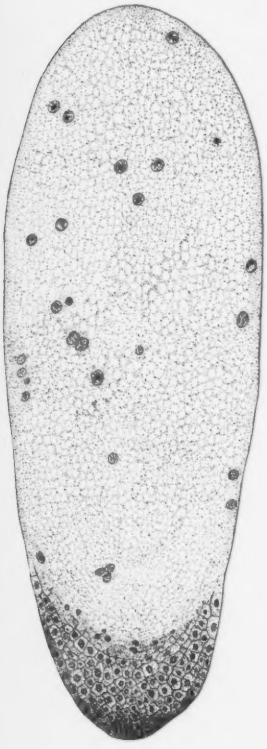
Fig. 14. Three embryos in about the same stage as that shown in the preceding figure. × 45.

FIG. 15. Tip of young embryo pressing into the endosperm. × 185.

FIG. 16. Young embryo with a portion of the suspensor. × 140.



COULTER and CHAMBERLAIN on ZAMIA



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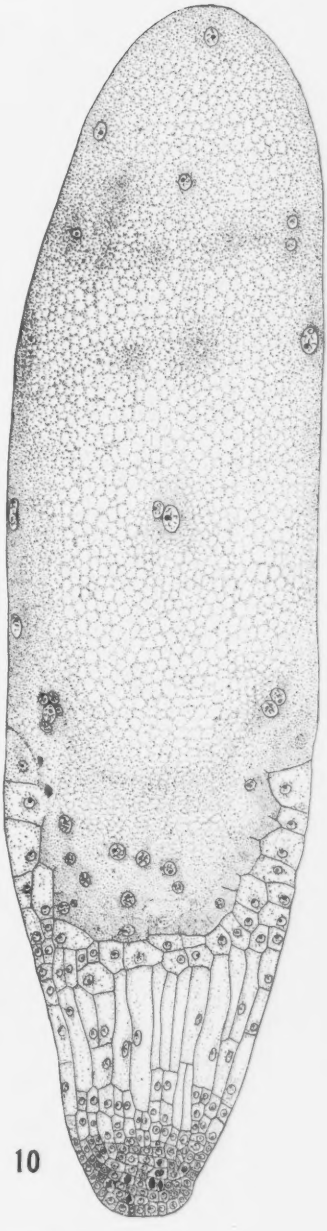

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COULTER and CHAMBERLAIN on ZAMIA

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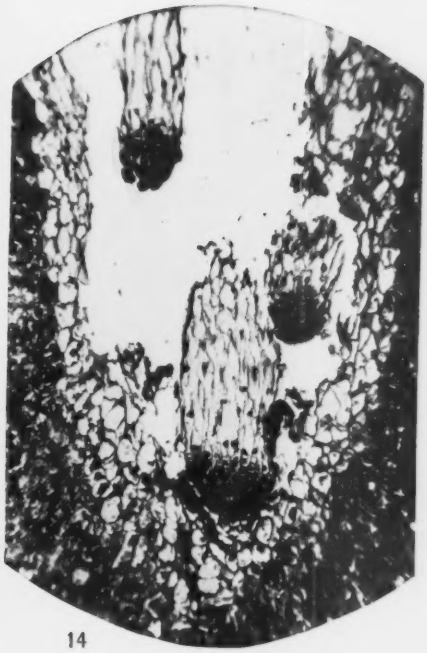

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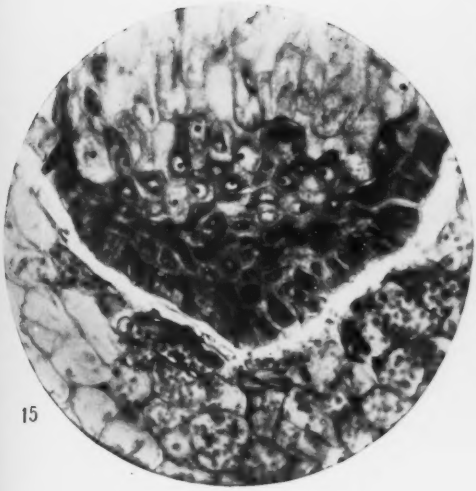

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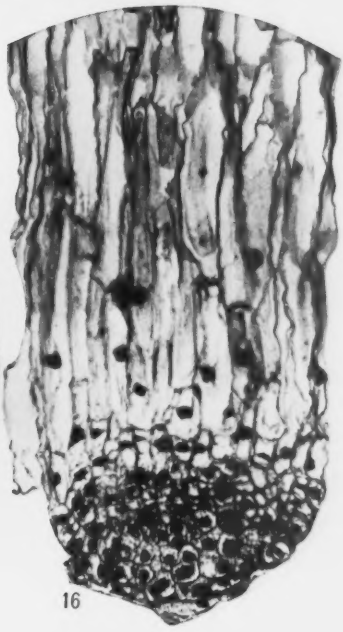

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COULTER and CHAMBERLAIN on ZAMIA

SOME TALUS CLADONIA FORMATIONS.

BRUCE FINK.

(WITH FIVE ILLUSTRATIONS)

DURING the summer of 1897, while studying the lichen flora of the north shore of Lake Superior, the luxuriance of certain lichens growing on talus attracted attention. The field work was being done for the Minnesota Botanical Survey, and an illustration of one of these unusually large lichens, a cluster of *Cladonia rangiferina* two and one-half feet in diameter and standing fully ten inches high, has already appeared in *Minnesota Plant Life*. During the summer several talus lichen societies were hastily examined, and it soon became apparent that luxuriant growth is by no means the only interesting feature of such plant societies. The object of the survey was taxonomic rather than ecologic, and in a field where many of the lichens were new to the writer, it was found to be practically impossible to secure the data necessary for a study of ecologic problems without seriously interfering with the main object of the expedition. Not until the summer of 1902 was it again found possible to visit the region and secure the desired data. Of course the tali studied in both years all lie within the state of Minnesota. During the season of 1897 tali were observed and somewhat studied along the international boundary between Grand Portage and Gunflint, and farther south at some distance inland in the Misquah Hills, as well as in the Sawteeth Mountains along the shore of Lake Superior. In 1902 efforts were confined to the region along the lake shore, an area not easily equaled in interest as to lichen flora.

On the whole it may be said that such talus lichen societies as will be considered in this paper are among the most interesting of lichen communities. Yet it must be added that they are quite as rare as interesting, or that, growing where they are very difficult of access, they are rarely seen. The composition of such

lichen societies varies with surrounding ecologic conditions. The most apparent of determining factors are the age of the talus, amount of light, shade, and moisture, nature of surrounding vegetation, and edaphic conditions respecting presence or absence of humus upon the lichen-bearing rocks. The age of a given talus is by no means an easy matter to determine. The tali bearing the plant societies under consideration are all surely postglacial, for the old shore lines of Lake Superior extend to or above their bases. So much for a maximum age; now for a minimum. The writer does not know of any igneous or metamorphic rocks, such as those bearing the lichen societies now under consideration, exposed within the last quarter of a century and bearing any considerable number of foliose or fruticose lichens, if indeed any kind whatever. Lichens do take possession of burned-over ground and old stumps to some extent in half the time indicated above, but not the more resistant rocks. Relative age of tali may of course be ascertained to some extent by the age of the trees found growing upon them; but lichens do not gain a foothold on the hard Algonkian rocks rapidly, and the changes in lichen population go on so slowly that little can usually be learned as to exact time involved in the establishment of the lichen population of a given talus. However, tali may be found that are comparatively very young and totally devoid even of the pioneers among rock-inhabiting plants, the crustose lichens; and every gradation of course may be found between this condition and old tali so overgrown with trees and covered with mosses, lichens, and humus that the talus blocks are in places not easily detected. These old tali, for reasons stated elsewhere in this paper, support lichen societies composed for the most part of foliose lichens or fruticose forms, especially the Cladonias, and more commonly these fruticose species in ombrophytic associations. Thus relative age, really of greater interest in ecologic consideration of such slow-growing plants as lichens than absolute age, may be easily ascertained for lichen societies growing upon tali whose conditions as to light or shade, moisture, and surrounding vegetation are similar.

In the field work it was not possible, in the limited time, to

examine a large number of tali. Consequently, three tali bearing quite different Cladonia-formations, growing under different ecologic conditions, were selected for special study.

The first lichen society to be considered in this paper may be designated as a *Cladonia gracilis formation of shaded talus*, and the second and third may be appropriately called *Cladonia rangiferina formations of shaded talus*. The two types are quite dissimilar, as in the first one finds *Cladonia gracilis* and other smaller Cladonias prevailing to such an extent as to be the only small plants to attract the notice of a casual observer; while in societies of the second type *Cladonia rangiferina* and other large closely related Cladonias are, at least on certain small and apparently rather young tali, even more predominant. In some localities, as on the north side of Carlton Peak, may be found tali bearing Cladonia-formations containing both the large and the small Cladonias in about equal proportions. The causes of the differences in composition of these Cladonia-formations are not always easy to trace. Under like conditions as to substrata there may be a succession, the larger Cladonias following the smaller, but quite as often species of Cladonia seem to follow the crustose or the foliose lichens, some species of which disintegrate the rocks sufficiently to form a beginning of humus on which the Cladonias may become established. In instances of this kind the Cladonias that gain a foothold may be the larger or the smaller species according to surrounding ecologic conditions. If the lichen society is surrounded with large trees, containing a good number of conifers, and especially pines, the large *Cladonia rangiferina* and closely related species will predominate. If the trees surrounding or growing upon the talus are small, and especially if devoid of conifers, the smaller *Cladonia gracilis* and other small Cladonias will prevail. If trees are growing upon the talus, of course they are younger than the talus on which they grow, and relative age of such tali may be estimated somewhat accurately by the size of the trees growing upon them. The talus on Hat Point at Grand Portage, to be mentioned again, estimated thus is the oldest one, and the one at Howenstine Bluff (*fig. 1*), to be considered later, is the

FIG. 1—General view of a portion of the talus and face of Howenstine Bluff taken from a point just below the tree line, showing talus blocks, old logs, more or less of the lichens growing over them, and shrubs and trees in various positions.

youngest of the lichen-bearing tali studied. Of course fires have run over certain tali and destroyed the plant life. In such instances the age may, for our purpose, be estimated from the time when the fire destroyed the lichens and other plants; for we are really interested in the age of plant societies.

On the old talus at Hat Point the lichen clusters, in the more shaded spots, are being driven out by the mosses, and the lichen-formation may be said to be scattered.[1] Yet the Cladonias of such societies are the most luxuriant known to the writer. On the tali which seem younger, or which do not present quite so purely ombrophytic conditions, the lichens occupy nearly the whole of the surface. The last formation to be considered below is such a one. Before passing to consider the individual formations it may be well to state that the Cladonias are found so densely congregated upon certain tali because better adapted to the environment than other plants, with which they cannot cope so successfully in the surrounding woods, though the lichens of the tali occur more or less commonly in the woods also. Further it may be said that these Cladonia societies of the tali always attract notice and special interest.

Passing to the consideration of the formations, the one that has been designated the *Cladonia gracilis formation of shaded talus* may be taken up first. The lichen society of this type to be considered especially occurs upon the talus on the north side of Howenstine Bluff, about a mile west of Grand Marais Bay, at Grand Marais, and is the best example of such lichen society known to the writer. The bluff faces to the north and rises forty-five feet above the level ground at the base to the northward. The lower two-thirds of the face of the bluff is covered with talus blocks of various sizes, and the face of the talus rises at an angle of about 35°. The base of the talus lies about forty feet away from the base of the bluff face, and fully one-third and in some places half way up from the base the talus is covered with a more or less dense growth of trees of moderate size, whose branches overhang the talus rather more than half way up to the bluff face. Thus taking into account both the

[1] FINK, B., Minnesota Botanical Studies 2:300. 1899.

trees and the north exposure of the bluff face, the sun can shine upon the talus not more than an hour or two each day. Further, partial shade is afforded by a line of shrubs, six to ten feet high, growing along the bluff face at the top of the talus (*fig. 1*). The face of the bluff above the talus is covered with species of Stereocaulon, Cetraria, Ramalina, Buellia, Usnea, Lecanora, Alectoria, Evernia, and Pannaria, while the talus below is covered with a perfect maze of Cladonias and mosses, with species of Stereocaulon, Peltigera, Sticta, and Parmelia interspersed here and there. The Cladonias have doubtless wandered to the talus from the level woods to the north below and yet more from the south on top of the bluff, and are especially numerous as to individuals and species because such an ombrophytic habitat is well adapted to the development of lichens having erect podetia surrounded by a protective pseudo-cortex of densely interwoven hyphae. These podetia are of course through the cortical hyphae protected against too rapid evaporation of moisture, and thus the Cladonias are able to rise from the substratum in a more or less erect position and successfully compete with the mosses for possession of the talus blocks.

The species and varieties easily detected in an area of the talus one rod square are *Cladonia gracilis*, *C. gracilis dilatata*, *C. cristatella*, *C. verticillata*, *C. verticillata evoluta*, *C. furcata paradoxa*, *C. fimbriata*, *C. fimbriata apolepta*, *C. fimbriata subulata*, *C. fimbriata radiata*, *C. bacillaris*, *C. deformis*, *C. pyxidata*, *C. cenotea*, *C. coccifera*, *C. squamosa*, *C. caespiticia*, *C. uncialis*, *C. rangiferina*, *C. sylvatica*, and *C. alpestris*. Of these the first and its variety (*fig. 2*) are especially abundant, though all but the last half-dozen are common enough. From the tree line to the base the talus is literally covered with Cladonias, of which the one for which the formation is named predominates even more largely than on the portion of the talus above the tree line. On this lower shaded portion of the talus, the Cladonias grow most abundantly on the old logs that cover the greater portion of the base of the talus. Unfortunately, it was found necessary to remove a few of the trees, shrubs, and logs growing upon

FIG. 2.—Detail of an area of the Howenstine talus one foot square, taken just above the tree line and covered with a dense growth of the most conspicuous plant of the society, *Cladonia gracilis*, and eight or nine other Cladonias in small numbers.

the talus to get a good general view, and it may be said that the presence of old logs upon the talus is an ecologic factor of considerable importance, as these smaller Cladonias are usually abundant on and about such decaying logs in favorable habitats.

It is an interesting fact that such societies of the smaller Cladonias are usually found in regions recently burned over, while those containing the large *Cladonia rangiferina* and its allies are more common in regions not recently burned and containing large conifers, especially pines. There is good evidence that the *Cladonia gracilis* societies may become established in soil-covered burned areas in ten or fifteen years, and the name, *Cladonia gracilis formation*, may be applied to other lichen societies than those of the talus. Frequently, however, the less conspicuous *Cladonia cristatella* or *Cladonia verticillata* predominates in these societies of the soil-covered areas. Finally, it is reasonable to suppose that much longer time would be required for such a plant society to become established upon the talus than upon the soil.

Cladonia rangiferina and its allies are frequently seen wherever conifers grow in the region, but nowhere else in such abundance or luxuriance as on the shaded tali. Botanists have frequently noted the fine Cladonias of Isle Royale in Lake Superior eighteen miles east of Grand Portage, Minn. I have not seen Cladonias growing on tali on the island, but have examined them somewhat under the conifers along the shore line and have seen none equal in size to those of the tali in the Sawteeth Mountains. The writer has studied these somewhat carefully and has found them best developed at Grand Portage and Grand Marais. The *Cladonia rangiferina* formation is best developed on the east side of Hat Point near Grand Portage. The point is about one hundred rods wide at the landward extremity and extends out into the lake somewhat more than a mile, in a southeastward direction, to a lakeward extremity which is only four or five rods wide. To the landward end, Mount Josephine rises about 800 feet above the lake, and from Mount Josephine to the lakeward end the point gradually decreases in elevation as well as in

FIG. 3.— A cluster of *Cladonia rangiferina* nearly three feet in diameter, taken from the Hat Point talus. A portion of a cluster of *Cladonia alpestris* is also prominent in the figure.

width. The ridge of the series of hills extending from Mount Josephine to the extremity of the point lies to the northeast of the central axis of the point so that the descent to the lake level on this side is quite precipitous. A large portion of this northeast side is covered with talus blocks, some of which are twenty-five to forty feet in their longest dimension (*fig. 3*). These blocks are overgrown with a forest of good-sized trees, principally conifers, and the whole talus-block floor is covered with such a growth of lichens and mosses as one seldom sees. During the first visit to the spot in 1897, fields of the larger Cladonias were found which looked at a distance much like the usual illustrations of coral forests. As nearly as I can recall, one such field covered more than an acre. It was almost completely covered with magnificent clusters of *Cladonia rangiferina*, *C. alpestris*, *C. sylvatica*, *C. uncialis*, and *C. amaurocraea*, and formed as beautiful and attractive a lichen community as one can well imagine. Some idea of the luxuriance of the plants may be had when it is stated that clusters were frequently seen from two to three feet in diameter (*fig. 4*). The talus with its great blocks, frequently thirty or forty feet long, and holes between, often twenty or thirty feet deep, is not easy to traverse, and it is not strange that in two days spent on the point in 1902 this wonderful Cladonia forest was not seen. At certain points the perpendicular rock face still remains above the talus and is in places from 100 to 200 feet high. The talus with its great blocks extends from 400 to 700 feet from the ridge or the perpendicular walls above to the water's edge below.

To compensate for failure to find the field of Cladonias above mentioned, a study of a somewhat similar one, though compact instead of scattered, may be presented. This formation may well receive the same name as the one just discussed. It occurs about a mile north of Grand Marais on the south slope of the Sawteeth Mountains. The formation is most luxuriant toward the more shaded basal portion of the talus (*fig. 5*), which is about sixty feet long and rises at an angle of approximately 40°. The characteristic plants of the society are *Cladonia rangiferina*, *C. alpestris*, *C. sylvatica*, *C. amaurocraea*, *C. uncialis*, and *Stereo-*

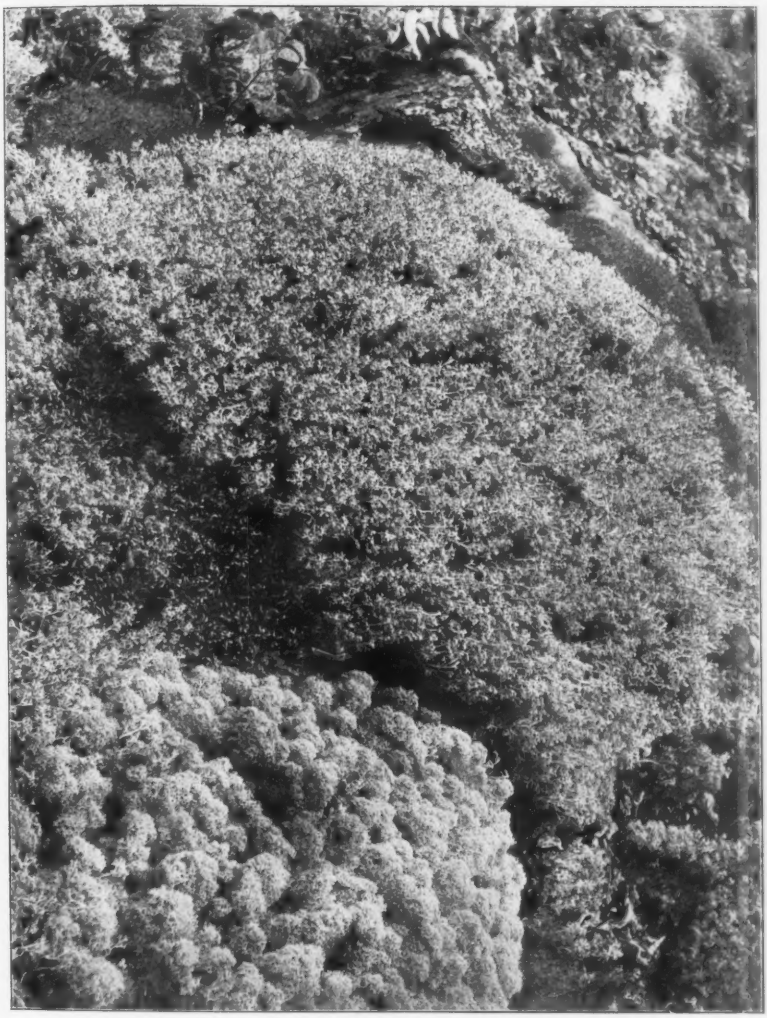

FIG. 4.— Small portion of the talus at Hat Point. The upper talus block is about 35 feet long, and its face and upper surface was found covered with Cladonias, other lichens, trees and shrubs, ferns and mosses. Cladonias are numerous on the smaller blocks in foreground.

caulon paschale. The more shaded basal half of the talus is so covered with these plants that a casual observer would scarcely notice the smaller and less numerous plants of the community. Yet a little closer observation brought to light a few ferns, quite a sprinkling of mosses, a half-dozen species of smaller Cladonias, and a few species of the foliose Nephroma, Peltigera, Parmelia, and Umbilicaria. On account of the less shaded conditions toward the upper part of this southward exposed talus, the Cladonias characteristic of the society are there less numerous and give way in part to the above-named foliose lichens and a number of species of the crustose Lecanora, Biatora, Buellia, and Lecidea. The talus sloping to the south is not, as hinted above, well shaded toward the upper part where the limbs of the large trees growing upon the lower part do not overhang. Of course the trees above a talus with south exposure do not furnish any considerable amount of shade. Consequently, rock decay has not gone on so rapidly toward the top of the talus, and neither this condition nor the lack of shade has been so favorable for the development of the erect-growing Cladonias. Hence there are present a large proportion of the crustose lichens upon the upper portion of the talus, these plants, in their closely adnate position upon the rocks, being better adapted to the more exposed portion of the talus because they easily hold the moisture between their lower surfaces and the rocky substratum and also readily absorb moisture from the rocks. The size of the trees would indicate that this talus is older than the one first considered and about two miles distant, and whether this is true or not, there is every indication that a fire ran over the one at Howenstine Bluff at no very distant day and killed the plant life of the spot so that the present growth is comparatively recent. The presence of a good sprinkling of old woody débris upon the talus now under consideration (*fig. 5*) shows that this condition alone does not indicate the presence of a Cladonia society composed of the smaller species. In this instance doubtless the *Cladonia rangiferina* society has succeeded the *Cladonia gracilis* community as the trees became larger, furnishing more ombrophytic conditions, and as the poplars and other deciduous trees

FIG. 5.—View of the talus on Sawteeth mountains, taken from a point 25 feet above the base of the talus and just above the tree line. Cladonias are conspicuous in the foreground.

gave way to a large extent to conifers, especially pines and cedars. In addition to the ecologic factors already noted, it may be said that protection from wind is a factor aiding in the development of the *Cladonia rangiferina formations*, as the plants of such societies can hardly endure the effects of strong winds.

It may be readily inferred from certain statements in this paper that it is by no means the intention to convey the impression that the Cladonia lichen societies are the only ones to be found upon tali. Other talus lichen communities, though not so striking in appearance, would doubtless prove to be quite as interesting if studied in detail. Such lichen societies as have been considered in the present paper doubtless occur in various portions of North America, especially in mountainous regions, and comparative studies as to ecologic conditions, adaptations, and species contained in the formations in various portions of our territory would be both interesting and instructive.

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BRIEFER ARTICLES

THE DEVELOPMENT OF THE MACROSPORANGIUM OF YUCCA FILAMENTOSA.[1]

CONSIDERABLE attention has been called to the species of Yucca on account of the curious symbiotism existing between them and the moth (*Pronuba yuccasella*) which is the principal agent in pollinating the stigma (5, 15). The very complete studies of Riley, Trelease, Engelmann, and others have related to the process of pollination by this moth and the parallel life-histories of the two organisms. My work has been on the embryology of *Yucca filamentosa* L., and the present paper treats of the development of the macrosporangium. In many points its development does not differ from that of the other Liliaceae which have been the subject of so much embryological research; but there are certain interesting deviations which may or may not be a result of the curious life-history of the plant.

The material used was collected in the summer of 1900 from plants growing in the botanical garden of the University of Michigan, and was fixed in Flemming's weaker killing fluid and in Worcester's killing fluid.[2] The ovaries were imbedded in paraffin, sectioned, and stained upon the slide. The haematoxylin stains of Kleinenberg and Haidenhain and picro-nigrosin were very satisfactory stains for nuclear study, while Zimmermann's fuchsin-iodin-green was the best for general cytological study. I wish here to acknowledge my indebtedness to Dr. James B. Pollock for criticisms and suggestions.

The anatropous macrosporangia are arranged in six vertical rows, two in each chamber, arising in acropetal succession from a ridged placenta. A hypodermal cell is early differentiated in the apex of each macrosporangium, from which two kinds of cells later originate.

[1] LXV. Contribution from the Botanical Laboratory of the University of Michigan.

[2] As I am not aware that the formula for Worcester's killing fluid is familiar to cytologists, I give it, as follows:

Mercuric chlorid, saturated aqueous solution	96 parts
Formalin (40 per cent. formaldehyde)	4 "
Acetic acid 10 per cent.	10 "
Formic acid to each liter of solution	5 drops

Wash in 70 per cent. alcohol.

It soon divides by a periclinal wall, forming a primary tapetal cell and a sporogenous cell. The primary tapetal cell subsequently divides by two anticlinal walls at right angles to each other, forming four (rarely two) tapetal cells which closely resemble the reproductive cells in size, contents, and staining qualities (*figs. 1, 2*). Other investigators (**4, 11**) have noted similar processes of division in monocotyledonous plants. The sporogenous cell, by two divisions, forms an axial row of four potential macrospores; frequently these divisions occur by walls all of which are perpendicular to the long axis of the ovule (*fig. 1*), but more often the walls between a_1 and a_2 are parallel or oblique to the axis of the ovule (*fig. 2*). So far as I know, no case has been reported where four potential macrospores have the arrangement shown in *fig. 2*.

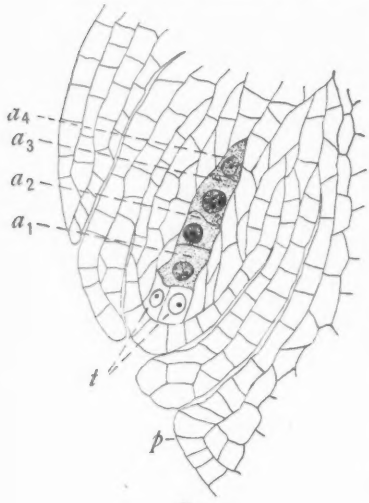

FIG. 1.

An axial row of four macrospores has been reported in a number of plants, some of the best-known cases being the Gramineae (**3**), many of the Rosaceae (**1, 14**), Elodea, Triglochin, Carex, Polygonum (**3**), Avena (**9**), Canna (**11**), Eichhornia, Pontederia (**8**), and probably in *Potamogeton natans* (**12**) and *Lilaea subulata* (**7**). Three macrospores occur in Orchis (**1, 14**), Allionia, Gomphrena, Geum (**3**), Naias and Zannichellia (**6**), two in *Convallaria majalis*, *Potamogeton foliosus* (**11**), and *Arisaema triphyllum* (**4**), except that in the last named they stand side by side instead of forming an axial row.

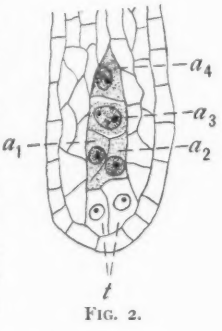

FIG. 2.

When the wall between a_1 and a_2, *fig. 2*, is nearly parallel to the plane of the section the axial row appears to have only three macrospores, but careful focusing shows that a_1 and a_2 lie one above the other. The cell at the basal end of the row is usually triangular.

Three of the cells of the row disintegrate. The survivor becomes the embryo-sac. There are indications that any one of the four mac-

rospores may become permanent, but in every case where I could be certain, a_8 was the nucleus which matured. Zimmermann's fuchsin-iodin-green was a very valuable stain for differentiating the reproductive nuclei from the vegetative nuclei, making it possible to distinguish the two with certainty. The cell which becomes permanent is often larger than its sister cells from an early stage; as it enlarges further, their walls break down and their contents are absorbed, leaving the macrospore in a long pointed cavity in the middle of the nucellus. The process resembles that described by Strasburger (1) in *Polygonum divaricatum*.

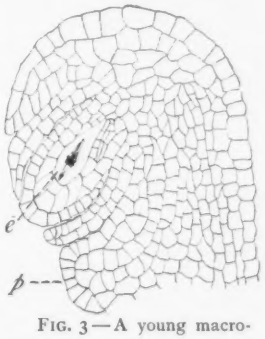

FIG. 3—A young macrosporangium at the time of the formation of the haustorial tube: *e*, embryo-sac mother cell; *p*, placenta. ×360.

The development of the macrosporangium in *Yucca gloriosa* has been worked out by Vesque (2), who described a hypodermal cell which gives rise to a two-layered tapetum and three potential macrospores, but did not follow the development far enough to determine which one persisted. There is no question, in all the cases which I examined, but that *Y. filamentosa* is constant in having a single layer of tapetal cells and that such cells as a_1 and a_2, *fig. 2*, are true macrospores. The fuchsin-iodin-green stain plainly differentiates the nuclei of the different cells. When disintegration begins the three macrospores disappear almost simultaneously, followed later by the tapetal cells.

The permanent nucleus now enters upon the divisions which produce the eight nuclei of the embryo sac. *Fig. 3* represents the first division and shows the shape of the embryo-sac at that time. The subsequent divisions are accomplished in the lower, pointed end of the cavity. The antipodal nuclei are often separated from each other by distinct cell walls. By the time the sexual nuclei are formed, the tapetal cells and part of the nucellus have disintegrated, leaving the apical end of the embryo-sac in contact with the epidermis of the macrosporangium.

The embryo-sac grows chiefly in the apical part at the expense of the nucellus and tapetum. The basal portion of the sac appears to sink deeper into the nucellus by reason of the elongation of cells in its walls, but it increases in diameter very slightly. The result of this manner of growth is to produce a narrow tube which penetrates the

nucellus nearly to the extremity of the fibrovascular bundle (*figs. 4, 5*). The migration of the nuclei into the tube and its relation to the fibrovascular system suggest that it may have a nutritive function, serving as an haustorium. This suggestion is further supported by the presence of fine granular material in the tube and in the cells adjacent to the fibrovascular bundles and the tube. If these are the granules of an organic acid, as their staining qualities indicate, or some form of plastic food material, then the migration of the nuclei may be considered a chemotactic response analogous to the growth of the pollen tube and the entrance of the antherozoids into the embryo-sac. Vesque (2, p. 304) found haustorial appendages in the embryo-sacs of Scrophulariaceae, Santalaceae, and Lathraea, and comments upon the parasitic nature of the embryo-sac in certain instances. A recent writer (13) reports the presence of haustorial appendages in certain of the Araliaceae.

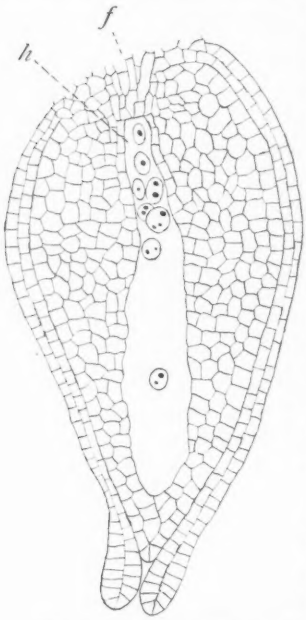

FIG. 4.—An embryo-sac in which the haustorial tube is fully formed and the divisions of the macrospore are completed: *f*, fibrovascular bundle; *h*, haustorial tube. × 360.

After the divisions of the macrospore are completed, the egg-cell and synergids move up to the apical end of the embryo-sac; the definitive nucleus also moves out, but often only to the mouth of the haustorial tube, sometimes to the middle of the embryo-sac; the antipodal nuclei usually remain in the tube.

Coincident with the divisions of the macrospore and formation of the embryo-sac haustorium, there is a rapid increase in the amount of nucellar tissue, an enlargement of the embryo-sac cavity, and a preparation for fertilization.

The columnar cells which serve as an epidermis to the placentae and to the macrosporangium are very large on that part which covers the ridges of the placentae and the basal part of the stalk of the macrosporangium. From these cells there exudes

a mucilaginous secretion a short time before fertilization occurs. The secretion passes outward in the cavity surrounding the macrosporangia, often forming a hood around each macrosporangium (*fig. 5*). In passing the micropyle the secretion often finds its way into it, and may force its way for some distance between the inner and the outer integuments. The question arises: Is not this an *artifact*, caused by some fault in the technique? The methods of preparing the material were varied until there was no longer any doubt as to their reliability and the identity of the secretion whenever obtained. A somewhat similar thing has been noted by Guignard (10) in the tulip. He speaks of papillae lining the wall of the cavity surrounding the macrosporangia, among which the pollen tube makes its way to the micropyle. Campbell also mentions the presence of secreting cells on the funiculus in Naias, but found no secretion. Wherever I have seen pollen tubes in my sections they have been growing in or toward this secretion. There is no evidence that this secretion has any distinctively nutritive function in itself, but rather that it serves as a medium through which the substance capable of attracting pollen tubes diffuses outward from the micropyle. If the colloidal secretion were nutritive, there would be an attraction of the pollen tubes into all parts of the secretion, but this is not the case.

FIG. 5. — A macrosporangium at the time of fertilization: *h*, haustorial tube; *s*, secretion from placentae. × 270.

The egg cell of the embryo-sac is fertilized shortly after the formation of the secretion. The results of fertilization are several: the formation of the secretion from the placentae ceases and all which exists disappears; the small rectangular cells on either side of the haustorial tube rapidly elongate, and the embryo sac enlarges in a transverse direction.—HOWARD S. REED, *University of Michigan.*

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FAXONANTHUS.

THE January number of the BOTANICAL GAZETTE, in a review of the first part of Professor C. S. Sargent's *Trees and Shrubs*, calls attention to the fact that a new genus, *Faxonanthus*, is therein described without mention of the family to which it belongs. The author of the genus desires to say that in the transcription of the original manuscript for publication a brief note on its affinity was omitted. It may be stated that the new genus *Faxonanthus* belongs to the Scrophulariaceae, and should be placed near the genus Leucophyllum.—J. M. GREENMAN, *Gray Herbarium.*

NOTES ON NORTH AMERICAN GRASSES.

I. ANDROPOGON DIVARICATUM.

ANDROPOGON DIVARICATUM L. Spec. Pl. 1045.— This North American grass has been neglected because it could not be identified. The description is meager and misleading. The first species of Andropogon described by Linnaeus, *A. contortum*, is now referred to Heteropogon. The second species is *A. divaricatum*, described as follows:

Andropogon spica oblonga, floribus lanatis remotis divaricatis: arista flexuosa nuda.

Lagurus humilior, panicula conica laxa nutante culmum terminante. Gron. Virg. 135.

Habitat in Virginia.

It is interesting to note that the *Index Kewensis* maintains the species, as Mr. Jackson had no reason for doing anything else with it. Mr. Munro in his account of the grasses in Linnaeus's Herbarium refers this to *Andropogon ternatus* Nees. Hackel in his monograph of the Andropogoneae suspects that it should be referred to *A. argyraeus* Schult., as *A. ternatus* is a South American species which Munro may have confused with *A. argyraeus*. I have recently examined the specimen of *A. divaricatum* in the Linnaean Herbarium and find that it is identical with his specimen of *A. alopecuroides* described as no. 4 of the *Species Plantarum*. The specimen, however, is quite fragmentary, consisting of a main axis with eight remote and divaricate branches, the whole forming an oblong spike about two inches long. The branches have from one to three spikelets. The plant was old, and all the others have fallen off. The spikelets are identical, however, with those of *A. alopecuroides*. In both cases the awn is twisted.

Linnaeus gives as synonym Gronovius 135. This is founded on Clayton's no. 600 from Virginia and is *Andropogon nutans* L. I examined this in the Herbarium of the British Museum where the plants of Gronovius are deposited.

The description of Linnaeus evidently applies to his own specimen rather than to Gronovius's plant. Strict application of the rules of priority would require that the specific name *divaricatum* be taken up for *A. alopecuroides*, which is an Erianthus, but as I do not wish to be quoted for such a binomial I do not make the combination. In this connection it may be noted that some botanists consider the twisted awn of Erianthus as a specific character. In Britton's *Manual* we have *Erianthus alopecuroides* (L.) Ell., but Elliott's plant has the

straight awn, hence on the above-mentioned basis *Andropogon alopecuroides* L. and *Erianthus alopecuroides* Ell. are not identical. My own opinion is that these, *E. saccharoides* Michx., and *E. compactus* Nash are all forms of the same species.

The third species described by Linnaeus is *A. nutans*. The plant in the Linnaean herbarium is what we have generally been calling by that name. Two synonyms are given. The first is *Andropogon folio superiore*, etc., of Gronovius based on Clayton no. 621, which is *Stipa avenacea* L. The second synonym is *Gramen avenaceum*, etc., Sloan, Jam. 35. Sloan's plants are also deposited in the herbarium of the British Museum. His plant is *Andropogon insularis* L.

The fourth species of Andropogon described by Linnaeus, *A. alopecuroides*, is founded upon a large panicle in his herbarium and upon Gronovius Virg. p. 133, Clayton no. 601, which is the same. The third synonym is Sloan, Jam. 3. Sloan's plant I take to be a different species of Erianthus.

II. DACTYLIS CYNOSUROIDES L.

DACTYLIS CYNOSUROIDES L. Spec. Pl. 71.

Dactylis spicis sparsis secundis scabris numerosis.

Gramen maritimum, spica crassa dactyloide terminali, odore rancido, culmo albo. Gron. Virg. 135.

β. Dactylis spicis alteriis secundis incisis erectis approximatis, calycibus unifloris subulatis. Gron. Virg. 134.

Habitat in Virginia, Canada, Lusitania.

Then follows a more extended description.

It is quite probable that Linnaeus may have included the two species that are now referred to *Spartina cynosuroides* Willd. and *S. polystachya* Willd. in the above, as he gives Canada as one of the type localities; while Merrill in his recent monograph of Spartina limits the range of the former from Canada to New Jersey and the latter from New Jersey to Florida. The two species were first distinguished by Michaux in his *Flora* as *Trachynotia cynosuroides* and *T. polystachya*. Michaux applied the specific names as have later authors under Spartina.

However, the specimen of *Dactylis cynosuroides* in the Linnaean Herbarium is *Spartina polystachya* Willd. (or Elliott, as Willdenow does not actually make the combination in his *Enumeratio*, but refers *Trachynotia polystachya* Michx. to Spartina). The specimen in the Gronovius Herbarium ("*Gramen maritimum*, etc.") is also *S. polystachya* Willd. Linnaeus's description might apply to either species,

but better to *S. polystachya*, especially the statement "calycibus mucronatis," for in *S. cynosuroides* the second glume is short-awned.

The locality, Canada, may refer to the variety β, which is *Spartina glabra* Muhl. both as to the plant in Herbarium Linnaeus and Herbarium Gronovius.

The Rochester code would require that the specific name *cynosuroides* be applied to the Linnaean plant, but I will leave the transfer for those who are thus inclined. According to the Kew rule the names are correct as now used under Spartina.— A. S. HITCHCOCK, *U. S. Department of Agriculture, Washington, D. C.*

CURRENT LITERATURE.

BOOK REVIEWS.

Pathological plant anatomy.[1]

WITHIN the past few years several books on plant pathology have appeared, some of them being of great value. They have dealt almost exclusively, however, with but one side of the question, the cause and prevention of plant diseases, rather than with the phenomena shown by diseased plants themselves. The work now under consideration, as its title indicates, takes up an entirely different aspect of pathology, viz., the anatomy of pathological growths. Such conditions as are mere degenerations, like the decay caused by many fungi, are not discussed, but those progressive anatomical developments resulting from pathological conditions or causing them. This book differs from others in which pathological anatomy is discussed in that the pathological structures are classified, not according to the external causes supposed to produce them, nor according to their place of origin on the plant, but according to their actual structure as compared with one another.

The five descriptive chapters take up the following main subdivisions of the subject: *Restitution*, the process of replacing lost parts, is treated here, since the formation of the reparatory tissue, like the formation of many pathological tissues, is connected with a utilization of energy, which is spared the organism that develops normally. *Hypoplasy*, the incomplete development of cells or tissue, may affect only the size or other features of development, as for example the amount of differentiation. *Metaplasy*, by which is designated every progressive change of a cell that is not connected with its abnormal enlargement or division. *Hypertrophy*, used in the sense that Virchow used it, designates the production of abnormally large cells, which may be single or grouped to form an abnormal tissue or organ. It is to be distinguished from the subject of the following chapter, *hyperplasy*, which, again in Virchow's meaning, is the abnormal increase in size of tissues or organs caused by an abnormal multiplication of cells. The last two subjects are extensively discussed, the former having the following subdivisions: hypertrophy as a result of suppression of the division of the growing cell where normally division should occur; as a result of etiolation; hyperhydric growth, including the so-called "oedemata"; tyloses; gall hypertrophies, *e.g.*, galls due to Erineum and Synchytrium; and multinucleate giant cells, occur-

[1] KÜSTER; ERNST, Pathologische Pflanzenatomie. pp. vii + 312. *figs. 121*. Jena: Gustav Fischer. 1903. *M* 8.

ring mostly in hyperplastic growths and forming a transition to that subject. Hyperplasy exhibits itself in two general types; homoeoplasy, where the elements of the abnormal tissue are the same as those of the tissue from which it is derived, and heteroplasy, where the elements are in part or all different. The latter contains by far the greatest number of cases. Under it are grouped most calluses, wound cork, wound wood, and the vast majority of galls. The latter are very extensively discussed. Most of the galls caused by parasitic plants come under the heading of kataplasms, while the highly organized galls, of definite structure and form, mostly of insect origin, are discussed under the heading of protoplasms.

The final chapter is devoted to theoretical considerations, and is in many respects the most interesting chapter in the book. Here are considered, so far as our knowledge will allow, the factors causing the various modifications of cells and tissues. The stimuli themselves are discussed, the reaction of cells and tissue to the stimuli, and finally the comparative sensitiveness of different tissues to the stimuli. This chapter, so far as it goes, is a valuable contribution to the study of the developmental mechanics of plants.

The illustrations are, as a whole, very good, as they illustrate clearly the structural features. They are, with few exceptions, line drawings, and a trifle over half are original. An extensive working bibliography is found in the footnote references.—ERNST A. BESSEY.

MINOR NOTICES.

STRASBURGER'S[2] *Das botanische Practicum* has reached the fourth edition. It seems safe to say that no botanical text-book of modern times is more fully abreast of the present state of knowledge. While the new edition preserves the general arrangement and sequence of subjects which have proved satisfactory in previous editions, each subject has been carefully revised and brought up to date, even matters like the latest investigations upon protoplasmic connections receiving attention. The newest methods in technique are also presented.

The indices are more extensive than in any previous edition, occupying 145 pages. There are five, as follows: I. An alphabetical index of the plants which are used as illustrative material. II. A list of plants used as illustrative material, arranged with reference to the time of year at which they should be collected. III. A list of stains and reagents. IV. Reagents, stains, plant substances, imbedding media, and sealing media; chemical exercises; instruments, apparatus, and their use; making of preparations; and physical exercises. V. General index. The first two indices will be suggestive and helpful to those who have the responsibility of keeping laboratories supplied with illustrative material. The fourth index is so full that in

[2] STRASBURGER, EDUARD, Das botanische Practicum. Fourth edition. 8vo. pp. 1 + 771. *figs. 230*. Jena: Gustav Fischer. 1902. *M* 20.

very many cases it will hardly be necessary for the well-informed teacher to look up the reference in the body of the book. This book is not to be confused with the *Handbook of Practical Botany* "by Dr. E. Strasburger," which is the fifth English edition of a translation by Hillhouse of an earlier edition of *Das kleine botanische Practicum*. Some of the defects of this English edition, which bears Professor Strasburger's name, although it does not represent his views, were noted in the April (1902) number of the GAZETTE.—CHARLES J. CHAMBERLAIN.

THE LAST two parts of Wiesner's[3] *Die Rohstoffe des Pflanzenreiches* have just appeared from the press of Wilhelm Engelmann. This completes the second volume and the work, and is accompanied by title-pages and index. Unhappily the latter is in two parts, one containing the names of crude materials and the other the systematic names of the plants from which they are derived. The two should have been combined, so as to make only one place to look for any item. But a thorough index is such a boon, and one so often denied us by German authors, that we readily condone a superfluity. The present double *Lieferung* contains the conclusion of the twenty-third section on *fruits* (pp. 801–871), and, far out of its place, the rest of the seventh section on *woods* (pp. 872–1027) by Professor Dr. Karl Wilhelm. In this part a description is given of the woods of deciduous trees, both as to their general and microscopic characters, with remarks on the uses to which the wood is put. Over one hundred kinds are described, some including several species. Of ten or a dozen the botanical derivation is not known.—C. R. B.

THE FIRST number of *Annales Mycologici* under the editorship of H. Sydow, announced in the BOTANICAL GAZETTE for December, has appeared. It contains 96 pages, and the following list of contributors gives promise of a very strong journal: P. Dietel, H. and P. Sydow, P. A. Saccardo, A. von Jaczewski, C. Wehmer, F. Cavara, L. Matruchot, P. A. Dangeard, and J. Bresadola. It should be suggested to the editor that a table of contents would make the journal much more convenient for consultation.—J. M. C.

NOTES FOR STUDENTS.

MOLISCH finds[4] that the red color produced in the leaves of a number of species of Aloe when brought into open sunlight from the greenhouse is not due to anthocyan but to the red coloration of the chloroplasts themselves.

[3] WIESNER, JULIUS, Die Rohstoffe des Pflanzenreiches. Versuch technischer Rohstofflehre des Pflanzenreiches. Zweite gänzlich umgearbeitete und erweiterte Auflage. 11 und 12 Lieferung. 8vo. pp. 801–1071. *figs. 249–297*. Index to both volumes. Leipzig: Wilhelm Engelmann. 1903. *M* 10. (Two vols. unbound, *M* 60; bound *M* 66.)

[4] MOLISCH, H., Ueber vorübergehende Rothfärbungen der Chlorophyllkörner in Laubblättern. Ber. Deutsch. Bot. Gesells. **20**: 442–448. 1902.

He finds red or red-brown chromoplasts also in seven species of Selaginella. The pigment proves to be a carotin.—C. R. B.

CENTROSOME-LIKE BODIES in the vegetative cells of the vascular cryptogams have been reinvestigated by Professor Němec.[5] The principal material was root-tips of *Blechnum braziliense*, *Diplazium pubescens*, *Dracaena arborea*, *Hibiscus calycinus*, and *Alnus glutinosa*. It was not difficult to find bodies which resembled centrosomes and would doubtless be interpreted as such by those who expect to find centrosomes in every cell. The writer comes to the conclusion, however, that there are no genuine centrosomes in the vegetative cells of the vascular plants, and unless blepharoplasts are centrosomes — and he believes they are not — that there are no centrosomes at all in vascular plants. The figures look like those which are familiar to any one who has made preparations of mitotic figures in root tips. Professor Němec states that with the same technique which he used for the root tips he was able to differentiate clearly the centrosomes of the liverworts.— CHARLES J. CHAMBERLAIN.

ONE MAY GET a very clear statement of Dangeard's[6] views on sexuality and related phenomena from a paper by him in *Le Botaniste*. Dangeard believes that the sexual act had its beginning through starved zoospores which fused with one another to satisfy this hunger. Sexuality was thus primarily autophagy. Parthenogenesis is to be expected whenever gametes find an environment sufficiently favorable for the vegetative activities common to all spores, *i. e.*, when taken out of their famished condition. These first principles form the basis of a discussion of reduction phenomena, the evolution and differentiation of sexual cells, a comparison of sexual processes in animals and plants, and other topics.

This is an interesting paper, presented in an attractive style. One must be cautious, however, in following Dangeard, for he deals with the most difficult field of speculative biology, where conditions are undoubtedly far more complex than is generally believed.— B. M. DAVIS.

RUHLAND[7] has made a preliminary report on the fertilization of some species of Peronospora and Sclerospora, and especially *Albugo Lepigoni*. The conditions in the latter are especially worth noting, since it adds a fifth form in Stevens's interesting series of four species in this genus (*Albugo Bliti*, *A. Portulacae*, *A. Tragopogonis*, and *A. candida*). *Albugo Lepigoni* has a very large coenocentrum and a much reduced receptive papilla, so that it stands at the *candida* end of the series. As a rule only one nucleus enters the ooplasm, taking its position near the coenocentrum, where it divides

[5] NĚMEC, B., Ueber centrosomähnliche Gebilde in vegetativen Zellen der Gefässpflanzen. Ber. Deutsch. Bot. Gesell. **19**: 301–310. *pl. 15*. 1901.

[6] DANGEARD, P. A., Théorie de la sexualité. Le Botaniste **6**: 263–290. 1898.

[7] RUHLAND, W. VON, Die Befruchtung von *Albugo Lepigoni* und einigen Peronosporeen. Hedwigia **41**: 179–180. 1902.

with a smaller nuclear figure than the previous mitoses in the oogonium. The evidence is not sufficient to justify the speculation that this is a reduction division. One of the daughter nuclei degenerates, the other becomes the female gamete nucleus and lies close to the coenocentrum, where it fuses with the male nucleus. The attraction of the coenocentrum for the gamete nuclei and its nourishing relations are especially evident.—B. M. DAVIS.

CZAPEK found in 1897[8] that a substance was present in geotropically stimulated roots which had a strong reducing action upon silver nitrate, and that in an unstimulated root there was less of it. He has now determined[9] that this substance is homogentisic acid, an oxidation product of tyrosin. The increase of homogentisin amounts at the maximum to 15 per cent., which is reached about the time the curvature begins to appear, from which time it falls off. (A similar phenomenon also occurs in phototropic organs on stimulation.) The zone in which it is found extends above the receptive zone to that of maximum growth. Czapek holds that his finding an increase of homogentisin in horizontally placed roots from which the terminal millimeter had been cut away excludes the strict form of Němec's hypothesis, that the starch-bearing cells of the root-cap *alone* constitute the perceptive organs for the geotropic stimulus. The accumulation of homogentisin in stimulated roots seems to be due to the temporary retardation of oxidative processes by special substances, soluble in water, insoluble in alcohol, and destroyed by heat. These Czapek suggests may be anti-enzymes, *e. g.* (anti-oxydase).—C. R. B.

ITEMS OF TAXONOMIC INTEREST are as follows: F. STEPHANI (Bull. Herb. Boiss. II. **3**: 98–129. 1903), in continuation of his *Species Hepaticarum*, has described 20 new species of Plagiochila from tropical Asia and Oceanica, and 82 from the antarctic regions.—C. MEZ (*idem* 130–146) has described 22 new species of Bromeliaceae.—A. S. HITCHCOCK (Bureau Plant Industry, Bull. 33) has published a revision of the North American species of Leptochloa, recognizing 15 species and excluding *L. Brandegei* Vasey.—F. S. COLLINS (Rhodora **5**: 1–31. *pls. 41–43*. 1903) has published a revision of North American Ulvaceae, recognizing 3 species in Ulva, 10 in Monostroma, 19 in Enteromorpha, and 1 in Ilea.—J. C. ARTHUR and E. W. D. HOLWAY (Bull. Lab. Nat. Hist. State Univ. Iowa **5**: 311–334. *pls. 1–9*. 1902) in their fourth paper describing American Uredineae deal with the rusts inhabiting species of Agrostideae and Chlorideae, including 16 species, one of which is new.—W. A. MURRILL (Torreya **3**: 7. 1903) has established a new family (*Xylophagaceae*) of the Basidiomycetes, based on *Xylophagus* Link and allied genera formerly included in Polyporaceae.—T. D. A. COCKERELL (*idem* 7–8) has described a new oak (*Q. Rydbergiana*) from New Mexico.—A. W. EVANS

[8] CZAPEK, F., Ueber einen Befund an geotropisch gereizten Wurzeln. Ber. Deutsch. Bot. Gesells. **15**: 516. 1897.

[9] *Idem* **20**: 464. 1902.

(Bull. Torr. Bot. Club **30**: 19–41. *pls 1–6*. 1903), in continuation of his "Hepaticae of Puerto Rico," has presented the genus Drepanolejeunea, including 10 species, and described 4 of them as new.—L. M. UNDERWOOD (*idem* 42–55), in publishing an index to the described species of Botrychium, has added 6 new species to the genus.—J. M. C.

THE REPRODUCTION of the interesting fungus Dipodascus, considered by some as one of the Hemiasci, is described by Juel[10] as follows: The sexual cells are multinucleate, the sexual nuclei being indistinguishable from the vegetative. After their union there is present a larger nucleus supposed to result from the fusion of two gamete nuclei. This fusion nucleus lies in the spore sac and gives rise to a large number of products which are much larger than the vegetative nuclei. The former become the centers of free spore formation and the latter remain with surplus cytoplasm in the sac. Juel regards Dipodascus as intermediate between the Phycomycetes and Ascomycetes. The spore sac is not homologous with an ascus but corresponds to a cell complex and consequently the form takes a low position in the series of Ascomycetes, near to but somewhat higher than Eremascus. There are lacking in Juel's investigation important stages in the nuclear history at the time of fertilization and during spore formation. These gaps make one hesitate to follow him in his views, and we are justified in asking for details on these points. It is not altogether clear that Dipodascus is an ascomycete. Perhaps it may be on a line by itself, with relationships somewhere among the molds. The sexual cells seem very close to coenogametes in spite of the fact that each is said to contain only one sexual nucleus, and spore formation in the sac, from Juel's account, does not seem like that in the typical ascus. Indeed, the spore sac suggests a germinating zygospore, perhaps exhibiting sporophytic tendencies which lead it to develop at once into a sporangium-like structure. These are some of the queries that present themselves.—B. M. DAVIS.

THE PHYLOGENY of the cormophytes, as indicated by their sporophylls and foliage leaves, is discussed in a long paper by Hallier.[11] The immense amount of detail and comparative morphology, especially in discussing the sporophyll, cannot be considered here, but a few of the conclusions and the principal features of the scheme of phylogeny may be of interest. Funiculus and integument correspond to a leaf pinna, on the upper side of which the megasporangium (nucellus) develops. The sporophyll of an angiosperm corresponds in general to the simple pinnate sporophyll of Cycas. In the Coniferales one, two, or more ovular pinnae are present, united congenitally by their edges. The staminate sporophylls of gymnosperms and angiosperms

[10] JUEL, H. O., Ueber Zellinhalt, Befruchtung und Sporenbildung bei Dipodascus. Flora **91**: 47–55. *pls. 7–8*. 1902.

[11] HALLIER, H., Beiträge zur Morphogenie der Sporophylle und des Trophophylls in Beziehung zur Phylogenie der Kormophyten. Jahrb. Hamburgischen Wiss. Anstalten **19**: 1–110. 1902.

are composed of two (seldom more) fertile pinnae and a sterile middle lobe, the latter being frequently suppressed. The typical staminate sporophyll of the angiosperms has come from the wedge-shaped or band-shaped sporophyll of the gymnosperms, Anonaceae, Magnoliaceae, Nymphaeaceae, etc. The sporophyte generation of the archegoniates is equivalent to the gametophyte generation, and has arisen from the gametophyte generation through the reduction of the sex organs. The archegoniates came from liverworts or algae, in which the two generations were equal in vegetative work and in which both generations had the dichotomous thallus. From this condition the sporophyte in the ferns advanced in its development, while in the mosses it degenerated and became dependent. All the Strobiliferae (cone-bearing pteridophytes and gymnosperms) have come from tree ferns of marattiaceous ancestry. The Gnetaceae are related to the Loranthaceae and Santalaceae; Ephedra, however, may be related to Casuarina and Myrothamnus. The Bennettitales are an extinct connecting link between the Cycadales and the Magnoliaceae. From the Magnoliaceae, directly or indirectly, come the rest of the dicotyledons, and also the monocotyledons, the latter coming from the region of the Ceratophyllaceae and Ranunculaceae.—CHARLES J. CHAMBERLAIN.

THE INFLUENCE of the nucleus upon the growth of the cell is described in a recent paper by Gerassimow.[12] The work is strongly supported by forty-seven tables which record the quantitative relations. Spirogyra was the plant used, and the conclusions depend upon a comparison of the behavior of nucleated and non-nucleated cells. Non-nucleated cells were obtained by disturbing the mitosis so as to move the nucleus from its central position toward one side; on the completion of the partition, one of the cells (in successful cases) would be left without a nucleus, although its chromatophores and other structures seem to be normal. As is known, Spirogyra divides late in the evening or at night, but division may be delayed until morning by lowering the temperature, the division taking place when the temperature is allowed to rise. The writer preferred to use material found dividing spontaneously. Such material was placed in a suitable vessel, surrounded by snow or crushed ice, and kept near the freezing point for about an hour, but was not allowed to freeze. It was then brought gradually to the room temperature. On the following morning many non-nucleate cells and chambers would be found. Although division may be induced by ether, this method was very little used. The following are some of the conclusions: The growth of a cell which has a superabundance of nuclear material is more vigorous than that of the ordinary uninucleate cell. The cell wall, the chromatophores, and apparently the protoplasm also grow more vigorously. Such cells divide only after they have reached a noticeably larger size. Non-

[12] GERASSIMOW, J. J., Ueber den Einfluss des Kerns auf das Wachsthum der Zelle. Bull. Soc. Imp. Nat. Moscow **1901**: 185–220. 47 tables and *2 pls.*

nucleate cells can grow somewhat in length. The non-nucleate chamber (which is distinguished from the non-nucleate cell by a larger or smaller opening in the partition separating it from its sister cell with the superabundance of nuclear material) grows more vigorously than the non-nucleate cell. Cells with a superabundance of nuclear material can conjugate with each other or with ordinary cells, and the size of the zygospore is in direct relation to the size of the conjugating cells.—CHARLES J. CHAMBERLAIN.

THE CONCLUSION of a paper by Matruchot and Molliard on the changes produced by freezing in the structure of plant cells, enables us to present a summary of their conclusions.[13]

The freezing of tissues always creates a demand for water at the exterior of the cell which produces a general and rapid outgo both of the water of the cell sap and the water of imbibition held by the protoplasm, resulting in a vacuolization of the latter, by which the cytoplasm becomes alveolar, and the nucleus a network of thick filaments and large meshes. The water once extracted from the plasma makes its way into the sap cavity either by simple osmosis, as is generally the case for the nucleus and probably for the cytoplasm, or by the bursting of the vacuoles and the escape of their contents outward, as in certain nuclei.

Exosmose of the water from the cytoplasm does not produce any easily observed structural modification. In the nucleus, however, the currents produced by the rapid exit of water in response to the demand from without, determino a uni-, bi-, or multipolar orientation of the nucleoplasmic framework, according as there are one or more directions of easy exit from the water. The "poles" are more watery and consequently less chromatic than the rest of the nucleus. They are always related in position to the sap cavity; the thinner the layer of protoplasm which separates the nucleus from the sap cavity the easier the exit and the more distinct the "pole." When very thin the wall of the nucleus may even be ruptured, letting the water escape bodily into the sap cavity.

The same alterations of structure as are produced in cytoplasm and nucleus by freezing can be produced by depriving them of water by other means, *e. g.*, by plasmolysis and by natural or artificial drying. The cytological evidence thus confirms Molisch's theory that death by freezing is in reality death by desiccation.

It will be evident at once that this paper has an important bearing upon certain cytological problems, since our modes of killing and fixing involve the relatively violent withdrawal of water, which the authors declare determines the orientation of nuclear material.—C. R. B.

SHIBATA[14] in an interesting preliminary paper records his experiments

[13] MATRUCHOT, L. and MOLLIARD, M., Modifications produites par le gel dans la structure des cellules végétales. Revue Gén. Bot. **14**: 401, 463, 522. 1902.

[14] SHIBATA, K., Experimentelle Studien über die Entwickelung des Endosperms bei Monotropa. (Vorläufige Mitteilung.) Biol. Centralbl. **22**: 705–714. 1902.

upon the structures of the embryo sac of *Monotropa uniflora*. Most of the observations were made upon material in the living condition. The interval between pollination and fertilization is dependent upon temperature. Under normal conditions fertilization takes place about five days after pollination, and on the same day or the next day from two to four cells are found in the endosperm. The fertilized egg elongates and bores its way into the nearest endosperm cell. Seeds ripen in about fifteen days after pollination, Light, atmospheric pressure, and mechanical injury of the ovule or other parts of the plant seem to exert no influence upon fertilization and subsequent phenomena, but the structures of the embryo sac are very sensitive to temperature. At 28° C. fertilization and subsequent phenomena proceed as at room temperature, and at 30° C. the endosperm nucleus can still divide; but at 31–32° C. fertilization can no longer take place, and disturbances are seen, due probably to increased osmotic pressure of the sac. By lowering the temperature the interval between pollination is lengthened, and at 8–10° C. fertilization is prevented. The experiments show that the polar nuclei may fuse in the absence of pollination, but that the fusion may be hastened or regulated by pollination; in normal cases the fusion occurs about five days after pollination, but when pollination is prevented, the interval may be prolonged to ten days or even longer. The three small antipodal cells disintegrate after fertilization, but when fertilization is prevented artificially, they may enlarge enormously and fill a considerable portion of the sac. At a temperature of 30° C. or higher there is no growth of the antipodals. Development of the endosperm can be induced experimentally in the absence of fertilization. When pollination is prevented, many of the ovules die within two or three weeks, but in others the sac enlarges and becomes filled with endosperm. In such cases the egg apparatus and often the antipodals collapse. This development of the endosperm was observed in 3 to 5 per cent. of the ovules, but at a temperature of 28° C., or by using osmotic solutions, endosperm was developed by 6 to 12 per cent. of the seeds. The writer believes that the endosperm nucleus has a stronger tendency toward parthenogenetic development than the egg. The full paper with plates will be awaited with interest.—C. J. CHAMBERLAIN.

IN THE January number of the *Revue Général de Botanique*, M. Luigi Macchiati announces his complete confirmation of the observation of Friedel (1901) that photosynthesis occurs *in vitro*, without the intervention of living protoplasm, by the action of an enzyme which utilizes the solar energy in the presence of chlorophyll. Several physiologists, including Macchiati and Friedel himself, repeated Friedel's earlier experiments with negative results. Now, however, Macchiati has obtained positive evidence, which he outlines, pending the publication of a more extended paper. Briefly his process and results are these:

Carefully washed leaves are extracted with equal parts of sterile distilled water and *c. p.* glycerin. The extract may be used or the enzyme obtained separately by shaking the extract with benzene, which is then decanted, carrying with it the enzyme, which settles as a flocculent amorphous precipitate. Other leaves, carefully washed, are dried at 100° C., powdered in a sterile glass mortar, and preserved in sterile glass with ground stopper. From the powder also the enzyme may be extracted, as it bears a heat of 100° for some time. Repeated extraction, washing, and drying frees it from the enzyme completely. The liquids to be tested were put into a beaker, in which is plunged an inverted funnel, having inverted over its stem a graduated test tube filled with liquid, into which the gases rise as they are set free.

Repeated experiments show that the glycerin extract from the living leaves or from the powder is unable alone to accomplish photosynthesis in light. On the contrary, the powder alone, if it contain the enzyme, when put into distilled water always causes an evolution of oxygen, and at the same time produces formaldehyde, the presence of the latter being demonstrable by the codein test. The enzyme is only able to produce photosynthesis in light if chlorophyll be present, which, as Friedel thought, seems to act as a sensitizer. The addition of an antiseptic, *e. g.*, $HgCl_2$ 1 : 2000, does not interfere with the process. CO_2 is absorbed from the air by the liquid in the beaker. The evolution of O is always proportional to the illumination. The leaves do not always yield the enzyme; they must be collected at a proper season.

These results seem not only to demand a new point of view regarding the nature of photosynthesis, but to furnish a new and strong support to Baeyer's hypothesis as to the process. At present the condensation of formaldehyde into a complex carbohydrate is not accounted for, nor do we know how a chemical sensitizer acts.—C. R. B.

THE PATH BROKEN by Jacobi (Flora **86**: 289–327. 1899) has been explored much farther by Treboux,[15] who agrees that even dilute doses of the stronger metallic poisons hinder photosynthesis in Elodea. Anesthetics and alkaloids act in the same way. Milder poisons such as KNO_3 exercise no very considerable influence until concentrated enough to plasmolyze the cell, when they permanently injure it. Acids, including carbonic acid, accelerate the evolution of oxygen in proportion to their concentration (within limits, of course). No evidence could be found for the formation of starch from formaldehyde, nor for any place for formaldehyde in photosynthesis. The Elodea used for these experiments, conducted in Leipzig, seems to have been a great deal more sensitive than the Chicago material (cf. the February number of the GAZETTE, p. 96).—E. B. COPELAND.

[15] TREBOUX, O., Einige stoffliche Einflüsse auf die Kohlensäureassimilation bei submersen Pflanzen. Flora **92**: 49–76. 1903.

A STUDY OF THE VEGETATION which has appeared upon Krakatoa since the destructive eruption of 1883 was made by Penzig[16] in 1897. The plants and their distribution he found in harmony with what could be expected from the report of the study made by Treub in 1886. The beach flora is the characteristic Pes-Caprae-formation of tropical islands, about twelve species composing it here. Beyond the beach, covering the lava hillocks and valleys, very tall grasses (*Gymnothrix elegans*, *Saccharum spontaneum*, and *Phragmites Roxburghii*) intermixed with vines (*Scaevola Koenigii*, *Ipomœa*, *Vigna*, etc.) predominate. Shrubs and other species are but isolated, so the vegetation may well be distinguished as a savanna. Above this, on the cliffs, ferns grow abundantly; while upon the more exposed rocks Cyanophyceae do the work performed in higher latitudes by lichens. In all 62 species (50 seed-plants and 12 vascular cryptogams) were found, as compared with 15 seed-plants and 11 ferns over ten years earlier. No mangrove trees grow about Krakatoa, nor as yet forest trees upon it. As to the means by which the island was seeded, it was learned that 60.39 per cent of the plants owe their arrival to ocean currents, 32.07 per cent. to the wind, and 7.57 per cent. to animals.—ETOILE B. SIMONS.

THE LIFE HISTORY of *Ruppia rostellata* is described in a recent paper by Murbeck.[17] It is suggested that pollination may take place under water as well as at the surface, although definite proof was not obtained. During the development of the microspores the tapetal cells break down, and their nuclei float free in the liquid which fills the cavity of the microsporangium. The formation of two definite male cells within the irregularly elongated pollen grain was traced in detail. A tapetal cell is formed, and the megaspore mother cell gives rise to four megaspores which are not arranged in a row, but the two lower spores lie one above the other while the two upper ones lie side by side or somewhat obliquely. This arrangement was observed in numerous instances. In one peculiar case the archesporial cell seems to have divided obliquely instead of by a pericline, and both resulting cells show the distinguishing characters of megaspore mother cells. In this mitosis, by which the archesporial cell gives rise to the tapetal cell and megaspore mother cell, the number of chromosomes was found to be sixteen. This number was also counted in other sporophytic cells. In the first division of the megaspore mother cell and also in the microspore mother cell the number is eight. The polar nuclei fuse completely before fertilization. Although the pollen tubes were traced to the embryo-sac, the actual process of fertilization was not observed. At the first division of the endosperm nucleus a wall is formed, dividing the sac into two chambers. The chamber at the

[16] PENZIG, O., Die Fortschritte der Flora des Krakatau. Ann. Jard. Bot. Buitenzorg **18**: 92–113. 1902.

[17] MURBECK, SV., Ueber die Embryologie von *Ruppia rostellata* Koch. Kongl. Svensk. Vetensk. Akad. Handl. **36**: 1–21. *pls. 1–3*. 1902.

antipodal end is small and its nucleus does not divide, but in the other chamber a large number of free nuclei are formed. A study of the embryo confirms the account of Wille that a primary root is formed at the base of the embryo, but soon disorganizes, and a lateral root, which is formed very early, is the first functional one. This is very different from the account of Ascherson in Engler and Prantl's *Die natürlichen Pflanzenfamilien*, and followed in Goebel's *Organography*, according to which this lateral root is the primary root, its unusual position being due to displacement.—CHARLES J. CHAMBERLAIN.

MISS SARGANT[18] has proposed a theory of the origin of monocotyledons based on her studies of seedlings of Liliaceae. The single cotyledon is regarded as being derived from two cotyledons by fusion. Among the large number of genera described, Anemarrhena is regarded as showing a primitive structure in the vascular strands of its seedling. The cotyledon of this plant shows two bundles with the xylem groups facing each other. This seedling is compared with that of the ranunculaceous genus Eranthis, in which the petioles of the two cotyledons are fused, forming a tube which contains two bundles; and the similarity is considered to be the result of inheritance from a common ancestor. Other genera of Liliaceae are described, forming series of increasing complexity, and the conclusion is reached that there is no true midrib in the cotyledons of this family. A consideration of other moncotyledonous seedlings follows, and the nature of the "monocotyledonous dicotyledons" is discussed, special reference being made to *Ranunculus Ficaria*, the single cotyledon of which is regarded as a fusion of two. Lists of dicotyledons with tubular cotyledons are given, and from the fact that practically all of these are geophilous plants she infers that the fused condition of the cotyledons in the monocotyledons has arisen in connection with the geophilous habit. — M. A. CHRYSLER.

TWO VERY interesting lichen-like associations of fungi with marine algae have been described by Minnie Reed.[19] She speaks of them as an Ulva-composite and a Prasiola-composite from the two algae concerned. The fungus in both instances is an ascomycete of the genus Guignardia, but the species are different.

Guignardia Ulvae n. sp. is associated with *ulva californica*, and the composite grows at "upper tide mark on the shady side of sandstone bowlders," at the entrance of the Bay of San Francisco. The Ulva-composite occurs in large and small patches, sometimes mixed with Ulva and Enteromorpha, and has been found at all seasons of the year with perithecia. The form of the plant suggests *Enteromorpha Linza*. Sections are striking because of the

[18] SARGANT, ETHEL, A theory of the origin of monocotyledons, founded on the structure of their seedlings. Annals of Botany **17**: 1–92. *pls. 1–7*. 1903.

[19] REED, MINNIE, Two new ascomycetous fungi parasitic on marine algae. Univ. Calif. Pub. Bot. **1**: 141–164. *pls. 15, 16*. 1902.

very large amount of the fungus. The algal cells are distributed singly or in groups, contained in capsules formed by a network of hyphae and in a gelatinous matrix. There is a central zone of mycelium so thick that the two layers of algal cells are widely separated. The perithecia are blackish swellings on the surface of the thallus, the cavity is lined with a pseudoparenchymatous layer from which the asci arise and there is a well-developed ostiole, lined with hairs that project outward. The ascospores are discharged in great numbers and germinate readily. It is probable that the germ tubes enter the Ulva sporeling at very early stages of development, and that they do not attack mature plants, for the latter have never been found partially infected. So the alga and fungus seem to develop together almost from the germination of the respective spores.

The Prasiola-composite came from Alaska. The fungus *Guignardia alaskana* n. sp. changes the character of the Prasiola plant (which is a new species, named *Prasiola borealis*), coloring it darker, and giving it a curled crinkled, and leathery texture in old plants. The monostromatic fronds become from 8–16 layers of cells thick after infection, and the algal cells are scattered very irregularly in the mass of mycelium. Another Prasiola-composite has been known for some years from the Antarctic, first described by Hooker (1845) under the name of *Mastodia tessellata*, its true nature being discovered by Hariot in 1882. The relation of the fungus to its algal host in these three composites is apparently essentially the same as in the lichens. The fungus must depend upon the alga for its organic material, and consequently operates as a parasite. Whether the alga gets any benefit from the association is very problematical. It is possible that the tougher texture of the frond may better resist wind and wave, but marine algae are generally well able to care for themselves in these respects and non-infected material grows successfully side by side with the composite plants.

It seems plain that these composite organisms are lichens, certainly as much so as is Ephebe, and we wonder if the author has special reasons for avoiding that name, and whether she thinks it should be replaced by a term indicating the dual nature of these plants.—B. M. DAVIS.

NEWS.

MR. C. G. PRINGLE is making a collection of Cuban plants in the vicinity of Cienfuegos.

DR. J. H. BARNHART has been elected editor-in-chief of the publications of the Torrey Botanical Club.

THE German Botanical Society has elected Professor Schwendener president, and Professor Wettstein vice-president.

PROFESSOR L. M. UNDERWOOD has gone to the West Indies to spend six months in the study of tropical American ferns.

PROFESSOR BRUCE FINK, of Upper Iowa University, has accepted the new chair of botany at Iowa College, Grinnell, Iowa.

PROFESSORS SOLMS-LAUBACH and GOEBEL have been elected honorary members of the Zoological-Botanical Society of Vienna.

JORDAN'S *Icones Florae Europae*, of which only 100 copies were printed, will be completed this year by the publication of the lacking 220 plates.

THE SHARON BIOLOGICAL OBSERVATORY, a summer school for teachers at Sharon, Mass., will experiment in forestry on a tract of 300 acres of woodland, which it purposes making into a model forest.

THE DESMAZIÈRES prize of the Paris Academy of Sciences has been awarded to Professor Roland Thaxter, of Harvard University, for his study on the parasitic fungi of American insects.—*Science.*

THE TASK of growing valuable forests on the barren sand-hills of Nebraska will begin this spring, when the Bureau of Forestry will seed about 100 acres of Dismal River Forest Reserve near Halsey with red cedar and jack pine.

JOSEPH BURTT DAVY, instructor in botany in the University of California, has accepted the position of state agrostologist and botanist to the Department of Agriculture of the Transvaal government, with headquarters in Pretoria.—*Science.*

WE ARE informed that the large private botanical library of the late Alexis Jordan, of Lyon (1814–1897), containing many valuable works on the flora of Europe, will be sold by auction next May. Paul Klincksieck, 3 rue Corneille, Paris, is preparing the catalogue and will send it free on application as soon as ready.

THE CONNECTICUT BOTANICAL SOCIETY was organized in New Haven, January 24, 1903, and the following officers elected: Professor Alexander W.

Evans, president; Dr. C. B. Graves, vice-president; Dr. E. H. Eames, recording secretary and treasurer; and Mr. E. B., Harger, Oxford, Conn., corresponding secretary. Thirty-one persons were present. Papers were read by Mr. E. B. Harger, and Mr. W. E. Britton, and a graphic account of "The geographic distribution of certain New England plants," was presented by Mr. M. L. Fernald. In conformity with a plan to collect material for a complete catalogue of the flora of the state, a committee on the higher plants, including the pteridophytes, was appointed, viz., Dr. C. B. Graves, New London; E. H. Eames, Bridgeport; Mr. C. H. Bissell, Southington; Mr. L. Andrew, Southington; Mr. E. B. Harger, Oxford; and Mr. J. N. Bishop, Plainville. Field meetings are to be held in some of the least known portions of the state, the flora of Northeastern Connecticut, for example, being almost wholly unrecorded.—E. H. EAMES.

FROM ADVANCE sheets of the *Report* of the Missouri Botanical Garden for 1902 we gather the following information: A series of plant houses of modern design and good construction were erected at a cost of $7,000. During the year, 128 species or varieties of plants were dropped from cultivation, and 1,712 were added, making a net gain of 1,584 for the year. The total number recorded as cultivated is now 11,551. Over two thousand plants were distributed to hospitals and schools, and 392 plants, cuttings, or packets of seeds were sent to correspondents of the Garden. In exchange for the latter material and the publications of the Garden, or as gifts, 11,613 plants and packets of seeds were received. The number of visitors in 1902 was 21,052 greater than in the highest previous year (1901) for which records have been kept, reaching a total of 112,314. The herbarium has been increased by the acquisition of the herbarium of Professor G. C. Broadhead, valuable as verifying the occurrence in Missouri of plants referred to in the early geological reports on the state, and by the incorporation of 62,844 sheets of specimens, of which 15,551 were presented or received in exchange for material or publications, 469 were collected by employees of the Garden, and 47,224 were bought. The herbarium, so far as now mounted, contains 427,797 specimens. The library has been increased by the addition of 1,524 books and 697 pamphlets, purchased, and 992 books and 1,995 pamphlets, presented or received by way of exchange. Among the notable additions to the library should be mentioned an extensive collection of books published before the time of Linnaeus, and therefore complementary to the pre-Linnaean library presented by Dr. Sturtevant in 1892. As now constituted, the library contains 22,608 pamphlets, 18,550 books, and 302,955 index cards. The current list of serial publications received includes 1,160 titles.